A MULTIPLE UTILITY APPROACH TO UNDERSTANDING CONSERVATION TECHNOLOGY ADOPTION: APPLICATION TO THE FLORIDA TOMATO INDUSTRY

BY

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By

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This dissertation builds upon current economic theory and methods to explain the adoption of water resource conservation technology. Most previous adoption research of modern irrigation technologies has not tested the behavioral assumptions of profit maximization and free choice. Using a multiple utility conceptual framework, operationalized through an expectancy-valence model, the adequacy of these assumptions are addressed. The dissertation explores the relevance of a social dimension and the effect grower perceptions of control (volition, ability, financial means) have on drip irrigation adoption decisions.

The adoption decision is modeled as a two-stage process: an initial threshold to adopt or not adopt and then the intensity of adoption. A double-hurdle econometric model is applied.

A standard derived demand model is first analyzed. The results indicate that the initial adoption decision is governed by product price and irrigation technology costs. The intensity of adoption, as measured by the proportion of farm area in drip irrigation, is determined by soil and water quality and the cost of pumping water.

The derived demand model is expanded into a multiple utility model by incorporating grower's pre-adoption attitudes towards drip irrigation, social norms related to the adoption decision, and perceptions of control, including free choice, over the adoption decision. In addition to price and cost variables, results show that these additional variables are needed to adequately explain and understand the initial adopt/not adopt decision. Water quality, crop price, pre-adoption attitudes and control are significant explanatory factors in the second stage decision.

Three conclusions are reached. First, on a theoretical level, there is demonstrated support for a multiple utility approach to grower adoption behavior. Second, the double-hurdle model adequately reflects the grower decision process. Third, policy recommendations should include more emphasis on extension, research, and market incentives with more attention to minimal justification, and less on command-and-control regulatory approaches, to foster adoption of water conserving irrigation technologies.

CHAPTER 1
INTRODUCTION

Background to Florida's Water Problem

Water use in Florida to satisfy human and environmental needs is increasing. The total amount of fresh water withdrawn in 1990 was 7,532 million gallons per day (Mgal/d) which represented about a 31% increase over freshwater withdrawals recorded in 1970 (Marella). There is increasing dependence on groundwater resources of which agriculture is currently the largest user. Despite relatively abundant supplies of ground and surface water, there is evidence of increasing water scarcity. High population growth rates, estimated at 33% between 1980 and 1990 (Marella), and the attendant requirements for domestic, industrial, and service sector water use, are driving an increased level of competition and conflict over water.

The major freshwater user in Florida is still agriculture. High value crops including fruits, vegetables, florals, and sod for suburban homes are dependent on irrigation. Relative to water uses for public supply, thermo-electric power generation, domestic use, and self-supplied commercial industrial use, agriculture accounted for about 62% of freshwater use from surface water sources and 43% from ground water resources in 1990 (Marella). At first glance, the dependence of Florida agriculture on irrigation seems an unlikely proposition. Although agricultural irrigation is supplemental in nature, generally poor, well

drained soils, high evapotranspiration, combined with relatively little rainfall during the growing season, has led to a dependence on ground water for crop irrigation.

Due to the fact that agriculture is the predominant consumer of fresh water resources, efforts are being made to ensure that producers employ water conserving technologies. The approach reflects the institutional structure that has evolved since passage of the 1972 Florida Water Resources Act (Florida Statutes, Chapter 373).

Institutional Environment

The 1972 Florida Water Resources Act (the Act) provides the legal framework for determining "reasonable-beneficial use" and for the allocation of the state's fresh water resources. The Act implements water use and allocation processes based on administrative law and is somewhat unique in that it represents a mixture of both western prior appropriation and eastern riparian doctrine (Maloney et al.). The mixture of western and eastern water law, and implementation through an administrative system in five regional water districts encompassing the State, has meant a central role for the state in water use decisions.

The Act mandates central control by giving freshwater resources the status of a publicly owned good. Private water use comes under control by the public sector. There is no private property in water, only use rights.

The Act requires (per amendment in the mid-1980's) the State's water management districts to establish a water use permitting process which assigns individuals, firms, and public water suppliers qualified use

rights to water (a Consumptive Use Permit). In order for a prospective water user to obtain a Consumptive Use Permit the proposed water use must be shown by the applicant to be reasonable and beneficial. Furthermore, water management districts have the authority to define and enforce rules and regulations designed to fulfill the Act's conservation objectives (See Lynne, Shonkwiler and Wilson for a discussion of the permitting process).

A main feature of Florida water law is the provision for using scientific information to manage and regulate the use of water resources. Florida's water management districts spend millions of dollars each year in water-related data collection and technology assessment. To promote the State's water conservation goals in the agricultural sector, districts set crop-specific water quotas and, in some cases, have mandated the use of specific water conserving technologies or management practices. The Districts try to persuade growers to voluntarily install these technologies, but the major approach has been through regulation. Water allocation criteria for Florida agricultural producers are based on administrative rules and regulations that require technical efficiency and reduced use. Some water districts set performance and efficiency standards to achieve water conservation. In reality, the standards dictate what technology must be used in order to obtain or renew a Consumptive Use Permit.

The Research Setting

Although recent research in Florida has shown that the amount of land in modern (low pressure spray and drip) irrigation technologies grew significantly between 1978-89 (Smajstrla; Boggess et al., 1993), the

causes of adoption have been the subject of little empirical research. The perception is that these systems have such significant technical and financial advantages over furrow and ditch or seep irrigation systems that they will be automatically adopted. However, the adoption rate of drip irrigation on tomatoes was estimated at only 21% in 1993 (Smajstrla). The low adoption rate indicates there is still inadequate knowledge of the environmental, socio-economic, and regulatory conditions or policies under which adoption of drip irrigation technology is more likely to occur.

This study, and the data used in the foregoing analyses, is based on survey data collected from 64 growers in three water management districts, representing 134 separate farms. The 64 respondents account for over 65% of tomato growers in the surveyed districts. Analyses was done at both the grower level (sample = 64), which is reported in Casey and Lynne (in press) and at the farm level (sample size = 134) which is reported herein.

Table 1.1 shows the geographic distribution for the entire sample and by water management district. The 134 surveyed farms represented nearly 28,000 acres of tomatoes. There were 19 growers interviewed in the Northwest Florida Water Management District, 31 in the Southwest Florida Water Management District, and 14 in the west coast area of the South Florida Water Management District. Approximately 44% of all surveyed farms were located in the Southwest Florida Water Management District, 25% in the South Florida Water Management District, and 31% in the Northwest Florida Water Management District.

Due to the larger field sizes in the Southwest and the South, these districts account for nearly 93% of the total acreage surveyed. While the average number of farms per grower is about the same across all three

Districts, the average farm size per grower varies tremendously. In the Northwest Water Management District the average farm size is about 100 acres, 434 acres in the Southwest, and almost 900 acres on the west side of the South Florida Water Management District.

Table 1.1 Geographic Characteristics of Florida Tomato Growers.

Characteristic	Entire Sample	Northwest Florida	Southwest Florida	South Florida
Number of Growers	64	19	31	14
Number of Tomato Acres	27,818	1,917	13,210	12,691
Number of Tomato Farms	134	47	53	34
Acres per Grower	435	101	426	906
Farms per Grower	2.09	2.47	1.71	2.43
Acres per Farm	208	41	249	373

Table 1.2 shows that the farms surveyed are evenly divided between mono-cropping and double cropping tomatoes with other crops. Although there is little difference between the number of farms mono- and double-cropped in the two southern water management districts, a much larger percentage of farms are double-cropped in the Northwest (about 64%). On a percentage basis, adopters of drip irrigation do less mono-cropping than non-adopters, but both groups have about half their farms under each type of cropping system.

Soil type characteristics of Florida tomato farms are shown in Table 1.3. Nearly all farms (82%) are classified as well to very well drained,

meaning that soils are predominately sandy. By water management district, most of the farms are classified as well drained; the highest level of

Table 1.2 Cropping Practices

Location or Adoption Status	Monocrop (%)	Double Crop (%)
Entire Sample	48.5	51.5
Northwest Florida	36.2	63.8
Southwest Florida	56.6	43.4
South Florida	53	47
Adopter	46	54
Non-Adopter	55	45

poorly drained soils is found in the South (about 24%). Of the 23 farms that were classified as poorly drained, 17 have drip irrigation. This finding contradicts the results of other studies where low adoption rates of drip have been associated with poorly drained soils, i.e., soils that have better water holding capacity and less need for precision irrigation.

Table 1.3. Soil Characteristics of Florida Tomato Farms.

Location or Adoption Status	Poor Drain (% Farms)	Well Drain (% Farms)	Extreme Drain (% Farms)
Entire Sample	17	69	14
Northwest Florida	17	72	11
Southwest Florida	13	72	15
South Florida	24	62	14
Adopter	18	72	10
Non-Adopter	14	64	22

The major water source for tomato irrigation is groundwater (Table 1.4.). Almost 80% of the farms use only well water for irrigating. About 20% of the farms use some surface water (creeks, ponds) for irrigation, but all of these except one are located in the Northwest Florida Water Management District. More than one-half the farms in the Northwest use only surface water, while over 90% of the farms in Southwest and South use only groundwater for irrigation.

Table 1.4. Irrigation Water Sources For Florida Tomato Farms

Location or Adoption Status	Ground Water (% Farms)	Surface Water (% Farms)	Ground and Surface (% Farms)
Entire Sample	77	19	4
Northwest Florida	47	53	0
Southwest Florida	96	0	4
South Florida	91	3	6
Adopter	68	27	5
Non-Adopter	97	3	0

Water quality differs over the study region. Seventy-seven percent of all growers reported no water quality problems. However, nearly 40% of the Northwest growers reported algae and mineral problems associated with the use of surface water. Over 85% of the farms in the Southwest and the South had no water quality problems. In previous research on drip adoption there has been found to be an inverse relationship between adoption and water quality. That is, the lower the quality of water pumped, the greater the adoption of drip irrigation. Most drip systems

come with a water filtering system, and when using surface water for irrigation the drip systems have proven to be superior to conventional sprinkler systems. The relationship between water quality and drip irrigation adoption appears to hold true in the study area. Of the 31 farms reported to have water quality problems, 30 use drip irrigation.

Problem Focus

There are two primary problems which this dissertation addresses. The first is the possibility that "between the claims of oneself and the claims of all lie the claims of a variety of groups." (Sen, p. 318) and thus, the possibility that mainstream, single utility economic models are inadequate to the task of providing an understanding of why growers adopt new irrigation technology. Family, friends, equipment dealers and water management districts (all having claims on the individual) may be influencing water technology decisions. Thus, theoretical and empirical models need to be sensitive to the possibility of social influence on adoption decisions.

The second problem addressed is to consider the role that Florida water regulations have played in the adoption of drip irrigation. Standard economic models may be theoretically inadequate because complete volition is presumed. However, Florida tomato growers do not have free volition to enter into a free market process to buy and sell water like with other inputs such as land, labor, and capital. Florida water regulations have been controlling in many cases, and this phenomenon needs to be considered in modeling grower's adoption behavior.

Research Hypotheses

Most economic literature addressing the adoption of resource conserving technologies rests on the hypothesis of profit maximization, and the pursuit of a maximum, single-utility associated with the satisfaction of self-interest. Adoption, or investment in modern irrigation technology, is induced whenever the choice results in increased farm revenue or decreased costs, with profits used to maximize self-interested utility.

Revenue can be enhanced either through direct and beneficial yield effects stemming from adoption of drip irrigation, or by switching to higher value crops which respond better to the new irrigation technology. Decreased costs can result from lower pumping costs per unit of water and from increased water-use efficiencies. Modern low-volume technologies can increase water-use efficiencies and extend the range of soil and water quality over which production can take place. Production functions that include very detailed information on the physical environmental characteristics of farms are used in most models investigating adoption behavior (Caswell 1991). In essence, the ability of modern irrigation technology to increase the quantity or quality of output or to decrease production costs results in increased farm income and motivates the decision to adopt. This view is summarized by Dinar and Campbell (p.5) who maintain that "Obviously the technology with the highest profit will be selected and its water use will prevail." Yet, human capital variables (age, years of farming experience, and education) or farm structure variables (farm size, firm organization, land tenure, irrigation management) are sometimes included in modeling the adoption decision.

While profit is undoubtedly an important motivating factor in irrigation technology choice, it is hypothesized in this dissertation that other behavioral factors suggested by the broader perspectives given in Sen (1977), Hirschman (1985), and Etzioni (1986) also motivate the adoption decision. These motives may include a sense of resource stewardship, the grower's desire to fulfill community norms with respect to technology decisions, and the degree of volition the grower perceives that he/she has over technological choice.

The major questions posed in this dissertation are the following: Have growers adopted water conserving drip irrigation technology? Why or why not? What is the motivation for adoption? Was it profit maximization, the desire to fulfill a personal community norm, or was it regulatory coercion? Do growers, for example, believe that neighbors, or an environmental group, or a water management district prefer he/she use a water conserving irrigation system? Is it important to growers that they comply with their wishes? To what extent are technology adoption decisions coerced or volitional in character? Could a coerced (e.g. by regulation) decision be considered a profit maximizing decision, which is the normal assumption in most economics studies about technology adoption currently reported in the literature? Could districts achieve greater water use efficiency by other methods? How can we determine this?

The major objectives of this research are to respond to the above questions and to test the hypothesis that decision-making with respect to adoption of drip irrigation technology involves a variety of competing motives, including but not limited to profit seeking. The importance of satisfying the individualist, self-interest goal of profit maximization in

the adoption decision will be compared to the importance of satisfying a grower's perception of community norms as well as the degree to which regulatory control affects the adoption decision. Profit seeking is hypothesized to be more as a continuous variable rather than a 0,1 dichotomous choice. Utility may be maximized by other means than increasing income.

The hypotheses presented rest on the notion of multiple utility as a conceptual framework for analyzing technology adoption decisions. The idea is that a grower may maximize his/her utility not only by adopting a technology that increases his/her own income, but can gain utility by satisfying his/her community norms related to water conservation. Additionally, because regulation acts as a constraint to technological choices, the concept of volition is important to understanding adoption decisions. Thus, a more general hypothesis to be tested is that a more complete model, including the grower's perception of community norms related to resource conservation, subject to the degree of volition affecting that decision, can improve understanding of and facilitate a more accurate, possibly even an improved, prediction of adoption behavior.

There are reasons for caring about social influence and the degree of volition in adoption decisions. First, empirical results from Hodges et al., Lynne et al. (1995), and Casey and Lynne support the conceptualization of a multiple utility function. Those studies indicate that the effect of social influences on strawberry grower adoption behavior and the degree of volition growers perceive they have over the adoption decision are as significant as the profit motive in the decision to adopt drip irrigation. Earlier research in Florida also suggests that

the presence of a conservation ethic and/or a sense of social responsibility may influence the adoption of soil resource conserving technologies (Lynne, Shonkwiler, and Rola).

Policy Concerns

There are important policy implications for what is essentially a regulatory institutional environment for agricultural water allocation and use. The first policy concern is whether grower's perception of coercion and control on the part of the districts have led some of them to purposefully avoid adoption of water conserving technologies, and in some cases, to operate at less than design efficiency. If this is the case, it might be reasonably expected that a command-and-control policy for achieving agricultural water conservation may fail in the long run. The implication for policy makers is that they must have a better understanding of the role of volition in grower's technology choices. How farmers function with respect to technology choice in this type of institutional command-and-control environment needs to be better understood.

The institutional environment may hinder, rather than promote, the adoption of water conserving technologies, and thus compromise the goal of increased water conservation in the agricultural sector (Lynne et al. 1995). In a command-and-control environment a grower's decision reflects less freedom of choice and is directly affected by the process by which the districts evaluate and select technologies and the district perception of how such technology fulfills the social preference for water conservation. Furthermore, the regulatory nature of water use rights

through permitting procedures and producer liability for externalities resulting from irrigation are institutional conditions that also affect growers technology choices. Florida's regulatory system has led to a situation where the standard economic assumption of complete volition, and the implications of this assumption for economic efficiency with respect to technological choice, is no longer representative. The extent of control could be adversely affecting economic efficiency in Florida agriculture.

Information gathered from surveying tomato producers shows they believe that district water use regulations and technology mandates are often uninformed, capricious, and detrimental to the economic viability of their farming activities. The number of regulations which set out to control agriculture has grown tremendously in the last few years and now take on the quality of micro-managing farm operations. There is resentment in the agricultural community over the intrusion of "inexperienced bureaucrats" to limit choices of the technologies and management practices they can employ on their farms.

The second policy concern is the uncertainty of water use rights. If the permitted entitlement to water use is perceived as insecure, as it is when water management districts periodically change irrigation performance criteria or change water quotas, then adoption of water conserving technologies may be adversely affected. Based on anecdotal evidence from grower interviews, insecure use rights in water sources may adversely affect the willingness of lending institutions to make loans for capital expenditures, and thus make it difficult or impossible for growers to invest in expensive modern irrigation technologies.

Another source of uncertainty associated with the way in which water is allocated and managed by the water management districts is the observation by growers they "never know what the district is going to make them do next." The uncertainty stems from the administrative process of water allocation and management. The process by which specific technologies or management practices are administratively mandated is dynamic, political, and characterized by uncertain outcomes. Outcomes are uncertain because the administrative process of selecting and mandating technologies or management practices involves negotiation and compromise. Thus, technology choice is defined and limited by the uncertainty inherent in the bargaining process.

The third policy concern is that if a water management district requires the adoption of specific technology or management practices there may be adverse consequences if certain groups of growers can not afford them or are unable to manage them efficiently. Thus, an administrative allocation of water through a permit system raises income redistribution issues. Hanneman, Lichtenberg, and Zilberman found that several farm bankruptcies occurred when growers had to adopt water conserving irrigation technologies to comply with California water pollution regulations. The same possibility exists for Florida farmers. There is evidence of fern growers abandoning local production for new sites in Central America (Casey et al.) and tomato growers relocating to Georgia due in part to the restrictive nature of water management regulations. The impact of water use and technology regulations on farmers' income may be a more important policy concern than their efficiency impacts (Boggess et al., 1993).

The primary goal of Florida's administrative water law is to protect and conserve the State's water resources. The question is not whether this should be the goal, but rather is there is a better way to achieve it that is more economically efficient and socially acceptable than is presently the case. Is the regulatory system that has evolved over the last twenty years the best way to handle the relationship between agriculture and water resources? Are there alternative policy approaches (e.g. incentives, more education) that can work better or be folded into the current institutions that may work better in the long run?

Not all of these questions can be completely addressed in this study. However, one key question is just how much involvement is required from entities outside the individual grower in order to satisfy both grower and social objectives in water use.

The Need to Focus on Actual Decisions by Growers

Identifying and understanding the factors that influence grower decisions to adopt modern irrigation technology is essential to determining an ideal mix of incentives and regulation. Growers can benefit from increased incomes through greater efficiencies in water use and fewer social costs associated with interference. Increased adoption may also have positive effects throughout the community in the form of greater employment in irrigation system manufacturing and maintenance, and more secure water resources for others in the community. The discussion needs to be shifted to determining the optimal level of regulation rather than eliminating it or increasing the level of coercion.

Organization of the Dissertation

The next chapter delineates the conceptual framework and the theoretical justification for employing a multiple-utility approach to technology adoption. The next three chapters consider three different sets of adoption literature. Chapter III applies a prototype of the standard agricultural economics conceptualization of irrigation technology adoption to the research data for the Florida tomato industry. A double-hurdle model of technology choice is introduced and results are compared with standard econometric tools used in previous irrigation adoption studies. Chapter IV operationalizes the multiple-utility framework by adding grower social norms to the technology adoption decision. Some methods are drawn from the social psychology literature to accomplish the test of multiple utility theory. Chapter V broadens the decision criteria by elaborating the concept of a constraint from the standard economic theory with the notion of control from social psychology. Associating the social psychology concept of control with the concept of a constraint facilitates actual testing of just how important the role of volition is to the economic decision, rather than simply presuming complete volition. Chapter VI concludes the dissertation with a discussion of three topics. The first is an evaluation of the alternative conceptualizations of human choice behavior related to the adoption of drip irrigation. Second, the implications of the findings on the factors affecting the adoption of water conserving technologies are discussed. Third, policy implications of the effect of regulation on technology adoption decisions are analyzed. The chapter concludes with policy recommendations which may serve to improve the way in which water management districts hope to achieve

greater adoption of water-conserving irrigation technologies in Florida agriculture.

CHAPTER 2
MULTIPLE UTILITY AND CONTROL AS A CONCEPTUAL AND THEORETICAL FRAMEWORK

Introduction

The conceptual model of irrigation technology adoption in this dissertation rests on a behavioral theory of multiple utility and incorporates grower perceptions of control over irrigation technology decisions. This approach is compared with the more limited view of current standard economic theory and most contemporary research on irrigation technology adoption: that the adoption choice is based solely on the basis of rational profit maximization in the pursuit of a single self-interested utility, within an environment of full volition, but also subject to constraints. The objective here is to build upon and enhance current theory, paying particular attention to the possibility of an individual multiple utility function in the absence of full volition.

Multiple Utility in the Evolution of Economic Thought

Adam Smith, Hume, Edgeworth, Walras, Bentham, and J.S. Mill all touch upon the dualistic character of human nature. For example, Smith not only addressed self-interested behavior in the *Wealth of Nations*, but also the benevolent behavior in the *Theory of Moral Sentiments* (Khalil; Evensky).

More recently, Sen's *Rational Fools: A Critique of the Behavioral Foundations of Economic Theory* (1977); Hirschman's *Against Parsimony:*

Three Easy Ways of Complicating Economic Discourse (1985); Etzioni's *The Case for a Multiple Utility Conception* (1986), and *The Moral Dimension, Toward A New Economics* (1988), and a test of multiple utility by Lynne et al. (1995), and Lynne (1995), all suggest a need for restructuring the single utility model with a broader conception of choice behavior. The common thread in this literature is that it attempts to integrate such concepts as commitment, values, and morality while building on standard utility theory. There is a gradual progression which starts with a recognition of the importance of these concepts in human choice behavior and results in a formal theory of multiple-utility, with additional attention to control.

Sen examines the assumption that choice behavior is solely based on self-interest, by emphasizing that, while the assumption is not misleading for certain activities, Edgeworth's general claim that there is no interest or value held with respect to communities is incorrect. As noted earlier, Sen's argument is that there are "claims between self and all others" (p. 318), in particular family and local communities. In the context of this study, local communities include such entities as water management districts, extension and experiment station personnel, and grower and environmental groups.

The major concern is whether the view of man as simply an egoist can achieve the general good. Sen writes:

> There is by now a long and fairly imposing line of economists from Adam Smith to the present who have sought to show that a decent decentralized economy motivated by self-interest and guided by price signals would be compatible with a coherent disposition of economic resources that could be regarded, in a well-defined sense, as superior to a large class of possible

> alternative dispositions. Moreover, price signals would operate in a way to establish this degree of coherence. It is important to understand how surprising this claim must be to anyone not exposed to the tradition. The immediate 'common sense' answer to the question 'what will an economy motivated by individual greed and controlled by a very large number of agents look like?' is probably: There will be chaos. That quite a different answer has long been claimed true and has permeated the economic thinking of a large number of people who are in no way economists is itself sufficient ground for investigating it seriously. (p. 320)

The revealed preference assumption provides a theoretical justification for why economic models treat man as behaving in his/her own self-interest. But the validity of revealed preference relies on another assumption: that people are consistent in their choice behavior. Consistency is another way of saying that people are rational.

Revealed preference "seems to be based on the idea that the only way of understanding a person's real preference is to examine his actual choices, and there is no choice-independent way of understanding someone's attitude towards alternatives" (Sen, p.323). Neoclassical behavioral models impose the requirement of internal consistency of observed choice, but Sen notes that "A consistent chooser can have any degree of egoism that we care to specify . . . (and thus) . . . the question of egoism remains completely open" (p.326).

In an effort to see choice as more than the expression of self-interest, Sen explores the social dimension of human behavior through the concepts of sympathy and commitment. Sympathy is defined by a situation in which the concern for others directly affects one's own welfare. It is akin to the concept of interdependent utility in the standard neoclassical

model. Sen distinguishes between sympathy and commitment in the following way.

> If the knowledge of torture of others makes you sick, it is a case of sympathy; if it does not make you feel personally worse off, but you think it is wrong and you are ready to do something to stop it, it is a case of commitment. Behavior based on sympathy can be egoistic, but action based on commitment is non-egoistic. While sympathy relates similar things to each other-namely welfares of different persons . . . commitment relates choice to anticipated levels of welfare." (p.327)

Seemingly, sympathy could be handled with the interdependent utility function. Alternatively, commitment seems to require a broader multiple utility conception.

Sen's definition of commitment is illustrated by the person who makes a choice he knows will result in a lower level of personal utility than an alternative choice. "(An) action is really chosen out of the sense of duty rather than just to avoid the illfare resulting from the remorse that would occur if one were to act otherwise" (p.327). The idea of commitment can be illustrated with Figure 2.1, following Lynne (1995).

Figure 2.1 seeks to portray a standard indifference map with a single budget constraint (p_1/p_2) for a two good market (q_1 and q_2). The exception is that there are two sets of indifference curves, U^I and U^{ME}, and two expansion paths, OAD and OCD, for a single individual. The U^I set of indifference curves illustrate the standard neoclassical assumption of an individual seeking to maximize his own self-interested utility subject to a budget constraint. The U^{ME} set of indifference curves illustrate an individual's utility gained from fulfilling his/her social norms. In the

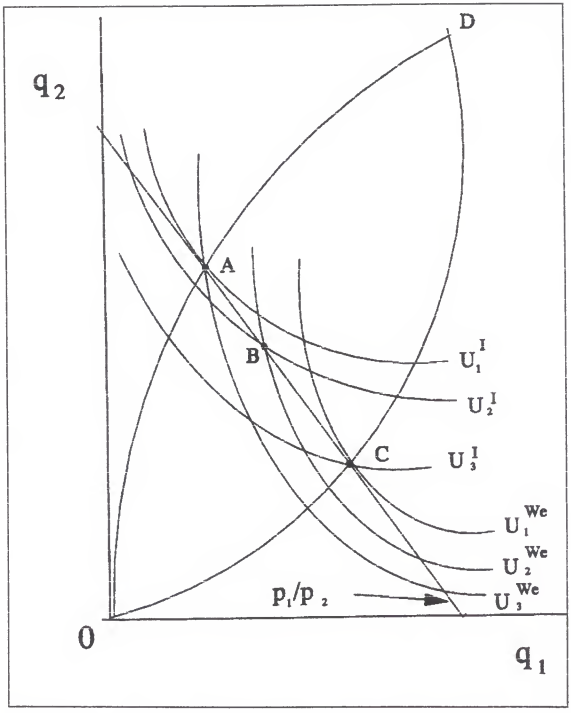

Figure 2.1. Indifference Curves Representing Self-Interested and Multiple Utility Concepts (Lynne, 1995).

language of Sen, different degrees of "commitment" are represented by the set of U^{*c} indifference curves. For reasons to be explained later in this chapter, points like A and C represent extreme positions for maximizing self-interested and social utility, respectively, for a given budget constraint. In reality, a position such as B may be selected as a compromise between the two types of utility.

For example, a person's choice that reflects both self interest and commitment may select B rather than A where $U^{I}_{2} < U^{I}_{1}$, illustrating the need for at least two utilities to model the type of behavior which reflects commitment, where commitment is represented by the U^{*c}_{2} indifference curve.

Because commitment implies making choices that are not completely in one's self-interest, the assumption that a chosen alternative is the best is not always realistic. This means that rational choice models need to be revised. Sen is concerned with that aspect of commitment which "drives a wedge between personal welfare and personal choice", whereas "traditional economic theory relies on the identity of the two" (p.329). In Figure 2.1, personal welfare would lie along OC and personal choice along OA. When there is identity of the two, both sets of utility curves lie on top of one another.

In the context of this study, adoption of drip irrigation technology is a choice where the concept of commitment is potentially important because one dimension of the choice may go against pure self-interested behavior. The possibility that growers may not make the decision to adopt drip irrigation solely out for reasons of self-interest, but may do so partially in response to a personal threshold of their social or community norms, makes it reasonable to postulate that commitment explains part of

their behavior. In a broader sense, commitment is connected "with ethics, since moral reasoning [reflected along OC] influences one's actions" (Sen, p.334).

Using the concept of commitment, Sen argues that traditional economic theory has too little structure. "The 'purely' economic man is indeed close to being a social moron" (Sen, p.336). This seems to suggest adding another set of indifference curves to add more structure: the U^{me} set reflects the utility the grower receives from satisfying his/her social norm.

To lend more structure to traditional theory by incorporating a social norm, Sen proposes a ranking of preference rankings which he calls a meta-ranking. A meta-ranking is a moral ranking of actions...but "actual behavior may be based on a compromise between claims of morality and the pursuit of various other objectives, including self-interest" (p.337). The meta-ranking is the genesis of the multiple utility concept.

As identified in Lynne (1995) Sen describes two salient features of a meta-ranking. First, the concept permits "a varying extent of moral articulation" (at points like B), and second, it "demands more information than is yielded by the observation of people's choices" (Sen, pp.338-39), i.e. we need a curve to represent U^{me}. We need to identify OC as well as OA and any intermediate paths towards point B. Sen applies the idea of commitment to the problem of the prisoner's dilemma:

> . . . some people find it puzzling that individual self-seeking by each should produce an inferior outcome for all . . . But the puzzle from the point of view of rational behavior lies in the fact that in actual situations people often do not follow the selfish strategy . . . In interpreting experimental results (game theorists) are tempted to put (this type of behavior) down to the lack of intelligence of the players . . . A more fruitful approach may lie in permitting the

> possibility that the person is more than the theory allows and that he has asked himself what type of preference he would like the other player to have, and on somewhat Kantian grounds has considered the case for himself having those preferences, or behaving 'as if' he had them. (pp.340-341)

One consequence of admitting commitment to standard economic theory is that "the empirical evidence of commitment cannot be sought in mere observation of actual choices, and must involve other sources of information including introspection and discussion" (Sen, p.342). Interpreting this, we need to investigate whether a U^{**} set of preferences exist.

The main issue, according to Sen, "is the acceptability of the assumption of invariable pursuit of self-interest in each act. Calling that type of behavior rational, or departures from it irrational . . . produces an arbitrarily narrow definition of rationality" (p. 343). Thus, being at a point like B or C in Figure 1 could in fact be quite rational. Sen suggests that traditional theory should be complemented with a structure that includes meta-rankings and that social groups or community provide the focus of many actions involving commitment. Sen's meta-ranking provides a structure of behavior that accounts for an individual's perception of what is good from the social or community perspective in addition to what is good from the own personal, self-interested point of view. The current neoclassical model has too little structure because it only requires the observation of choice presumed to be at point A to know preferences, whereas choice may reflect a previous compromise between self interest and commitment, such as point B.

Hirschman maintains that

> Economics as a science of human behavior has been grounded in a remarkable parsimonious postulate: that of the self-interested, isolated individual who chooses *freely* and *rationally* between alternative courses of action after computing their prospective costs and benefits. [But] . . . Parsimony in theory construction can be overdone and something is sometimes to be gained by making things more complicated. (p.7, parentheses and emphasis mine)

The implication is that there may be two sets of indifference curves

Building on Sen's concepts of commitment and meta-rankings, Hirschman observes that economics has traditionally dealt only with preferences that are revealed by agents as they buy goods and services. "The complex psychological and cultural processes that lie behind the actually observed market choices have generally been considered the business of psychologists, sociologists, and anthropologists" (Hirschman, p.8). Figure 2.1 proposes they become the business of economists in a theory of multiple utility.

Sen's idea of meta-rankings is carried further by Hirschman who maintains that without social norms any social system will crumble. Meta-preferences, as demonstrated by reflection prior to decision making, reflect social values or norms and are internal to the individual. Again, these can be seemingly represented in the OC path.

Hirschman also claims that

> one aspect of the process of choice and preference formation must be of concern to the economist: men and women have the ability to step back from their 'revealed' wants, volitions, and preferences, to ask themselves whether they really want these wants and prefer these preferences. (p.8)

This means that metapreferences may differ from preferences and that one can be on OC and peer back and consider OA, and even consider moving from OA toward OC. Neoclassical theory presumes that the paths become one,

eventually, but this ignores the dynamics of preference formation. Ultimately, meta-preferences may influence an individual's final choice.

An illustration of the relationship between preference change and metapreferences is given by noting Frankfurt's distinction of 'wanton' or 'nonreflective' changes in preferences or tastes.

> . . . the nonwanton change of preference is not really a change in tastes at all. A taste is almost defined as a preference about which you do not argue...A taste about which you argue, with others *'or yourself'*, ceases *ipso facto* being a taste it turns into a *'value'*. When a change in preferences has been preceded by the formation of a metapreference, much argument has obviously gone on within the divided self; it may represent a change in values rather than a change in tastes. Economists' have downgraded changes of the reflective kind into those of the wanton kind by assimilating them to changes in tastes." (Hirschman, p.9-10, author's emphasis)

Figure 2.1 shows that changes of the reflective kind may be pursued along OC and tastes along OA. A combination of the two changes is at point B, where, upon reflection, one takes a middle path.

Borrowing an example from Winston, Hirschman examines the difference between 'process utility' and 'goal utility'. Process utility states that "the means to the end of productive effort need not be entered on the negative side in a calculus of satisfaction" (p.12). This is illustrated by indicating that people may select an irrigation technology because they find the choice satisfies a community norm, partially at B or fully at C. Striving to fulfill this community norm, even though the prospect of profit is uncertain, can be thought of as an 'affective' or 'expressive' activity (Smelser; Parsons 1949, 1960), as opposed to purely instrumental activities. The utility set U^{m} reflects this emotional part and implies movement along OC, or from OA towards OC.

In response to the questions "But why should economics be concerned with all this? (and) Is it not enough for this discipline to attempt an adequate account of man's instrumental activities", Hirschman states that "as economics has grown more ambitious, it becomes of increasing importance to appreciate that the means-end, cost-benefit model (illustrated by movement along OA) is far from covering all aspects of human activity and experience" (p.14). His comment may also be true when one considers that a non-instrumental dimension of grower choice behavior may explain why some individuals invest in costly irrigation technologies.

Metapreferences complicate the analysis of choice behavior in the case of an individual who deliberates on whether to use more resources for "instrumental activities at the expense of the non-instrumental ones, and vice versa" (Hirschman, p.15). Shifts of this sort could mean an actual shift from one kind of activity to another (e.g. from public action to private pursuits). Hirschman's general conclusion is that the complexity of human nature must be reintroduced into economic theory in order for it to be more realistic. The fact that people are self-evaluating means that metapreferences must be taken into account when examining choice behavior.

The inclusion of metapreferences does not assume that choices are easy.

> There is tension between metapreferences and preferences, between instrumental and non-instrumental modes of behavior and action, between self-interest and service to community, or between 'interest' and 'benevolence', as Adam Smith put it. Economics has concentrated wholly on the instrumental mode . . . and needs to pay closer attention to the special nature of public morality as an 'input'. (Hirschman, p. 20)

Etzioni (1986) also argues for an alternative theory of choice behavior by "recognizing that individuals pursue at least two irreducible sources of 'utility', pleasure and morality" (p.159). Pleasure utility would be pursued along OA and moral utility along OC in Figure 2.1.

Etzioni (1986) identifies three different types of utility used in current economic theory. The first is utility based on self-interest. The second encompasses the utility an individual receives from "his own consumption as well as that of others" and "includes satisfactions derived from benevolent acts and a certain understanding of community minded duty or interdependent utility". The third type is utility as a "common denominator where all specific quests for satisfaction can be ranked, but has no substantive attributes" (Etzioni, 1986, p. 160). This last utility is referred to by Etzioni as "X-utility" and treats utility as an abstract concept, without content. It is a common denominator into which all "rank-orderings can be systematized" (Etzioni, 1986, p. 164). The difficulty with X- utility is that any ranking will depend upon the dimensions along which they are assessed.

Etzioni (1986, 1988), like Sen and Hirschman, considers the self-interested utility (along OA in Figure 2.1) too narrow a description of human behavior. Moreover, in this concept of utility, the ends justify the means; if the ends are good, the means are good. Thus, in the Benthamite tradition:

> Pleasure is invested with moral approval; it is good while pain is evil. (However), once this gross value judgement about the moral goodness of pleasure is removed, and one takes into account that numerous acts are either pleasurable or moral but often not both, the mono-utility world is undermined. (Etzioni, 1986, p.160)

Some economists (for example Becker and Stiglitz) argue that the self-interested version of utility can account for altruistic or community oriented actions. This is the essence of interdependent utility which assumes that the level of utility of one consumer depends upon the consumption of another. Etzioni (1986) suggests, however, that a utility that includes "commitment to values" (p.160) is very different. Like Sen, Etzioni maintains that acts of self-denial (commitment) are incompatible with the concept of interdependent utility. Furthermore, "to the degree that this [interdependent utility] aims to shed light on *motivation* it constitutes a conceptual failure, because the purpose of introducing concepts is to call attention to meaningful distinctions" (p.162, parentheses and emphasis mine).

The utility curves illustrated in Figure 2.1 are not interdependent in the way the concept is normally thought of, i.e. for the ith individual, $U^i_1 = f(q^i_1, q^i_2, U^i_2)$. Rather, the multiple utility model has the form of $U_i = U_i (U^i_1, U^{*i}_1)$ where $\partial U_i / \partial U^i_1 U^{*i}_1$ does not equal zero. The multiple utility function is different in its substance and implications. It cannot be reduced to a single overriding utility..

The importance of non-reducibility and distinguishing between behavior that is motivated by pure self-interest from behavior that is community oriented is illustrated by drawing on Adam Smith's claim that a well functioning market system relies on individuals seeking self-interest. The result is that the common good is achieved through maximizing self-interest in the market place. But, as Etzioni (1986) argues,

> If there is no fundamental difference between self-love and love for others Smith's whole thesis vanishes. Indeed, if

> people can derive pleasure directly form serving others and the community, there is no need for an invisible hand to tie their individualistic pursuits to the common good. Moreover, problems that might arise in coordinated, non-selfish actions would not necessarily be handled effectively by the invisible hand. It thus seems, on the grounds of sound conceptualization, that the quest for self-satisfaction and seeking to serve others (the public included) out of a sense of moral obligation, are to be kept apart. (p.163)

Lynne (1995, p.23) suggests this interpretation seems reasonable because "including the utility of others in the I-utility function suggests there is some conscious, non-invisible (visible) action at work, but yet the invisible hand idea suggests it is not necessary to have any such conscious action".

The multiple-utility framework helps explain preference dynamics. Similar to Hirschman, Etzioni draws attention to the case where people change their preferences as the constraints under which they implement them change.

> Without a conception and measurement of preference dynamics, in which values play a pivotal role, a satisfactory theory of economic behavior is hard to imagine. The economists's assumption that people's preferences are 'stable' ignores the most elementary observations of daily experience. (Etzioni, 1986, p.165)

In this study it would be reasonable to postulate that the changing nature of water use regulations or community norms would affect grower's decisions or "preferences" about drip irrigation technology. As water use regulations or norms change we may see a movement along path OA toward path OC in Figure 2.1. For example, movement toward OC may be caused by the diet and exercise that one's doctor and/or spouse wants you to pursue in place of greasy foods along OA. An intermediate point such as B may be selected for some time, but eventually one may move to OC and do exactly

what the doctor and spouse believes and values. One's personal tastes are merged, most likely with some conflict, with the perceived tastes of others in the community, including regulatory agencies.

Etzioni (1986, 1988) calls for developing a more complex theory of economic behavior. Noting that the multiple utility concept is not new, Etzioni remarks that previous writers have "accommodated (multiple) utilities into one overreaching one" (1986, p.166).

Etzioni's conceptualization of multiple-utility incorporates what he calls moral utility. An act is moral if it meets four criteria: an imperative, a generalization, a symmetry when applied to others, and one which is intrinsically motivated. An imperative is illustrated by persons who act morally (because) they feel "they 'must' behave that way, are obligated, duty bound . . . one ought to do something because it is right (movement along OC) as distinguishable from doing it because it is enjoyable" (movement along OA) (Etzioni, 1986, p.166). Moral principles are important and are set aside as differentiated. Morality is a source of commitment and affects choice. This may move you toward point B depending on how each person makes a trade-off between commitment and self-interest.

Generalization is defined by "individuals who act morally and are able to *generalize* in the sense of justifying their acts to others and to themselves by general rules" (Etzioni 1986, p.168). Symmetry requires "that there must be a willingness to accord other, comparable people under comparable circumstances, the same standing or right" (*ibid*). Affirmation means that moral acts affirm or express a commitment in that "they are intrinsically motivated and not subject to means-end analysis" (*ibid*).

They are acts that are motivated "by sense of duty or by some other internalized value" (Heath).

Traditional theory may recognize that moral factors can affect preferences, but these factors do not have to be considered separately because they are already supposedly mediated into individual preferences and, thus, it is unnecessary to investigate what lies behind preferences. We might envision another set of U^{**} curves that are intermediate between the two sets given in Figure 2.1, and tangent to the budget line at point B. There are at least two problems with this view. First, moral factors may not only affect preferences, but also constraints because "moral factors rule out options that are preferable from a maximization standpoint" (Etzioni 1986, p.169). Certain budget constraints comparing q1 and q2 are simply not considered. Secondly, "moral acts are a source of value and of motivation other than pleasure" and "many are explicitly based on the denial of pleasure in the name of the principles evoked" (*ibid*). Again, one may deny oneself from moving along OA and instead move along OC. For example, Etzioni (1986, p.173) cites experimental data that "supports the existence of altruism...behavior in which there is no pleasure for the ego, or the costs of egoistic behavior clearly outweigh the gains. The reward from altruism is the inner sense of having done what is right", i.e. either movement along path OC or movement from OA towards OC, at points like B.

Like Hirschman, Etzioni recognizes that there is often conflict and tension involved between self-interest and social utility: the OA and OC paths differ. Tension arises because there are times where self-interested and social goals calls on the same limited resources. This

observation seems particularly relevant to the potential trade-offs involved in grower adoption of water conserving drip irrigation technology.

The standard argument against the concept of multiple-utility which incorporates a moral or social utility is that moral factors can be explained by economic factors (Brennan 1989, 1993). However, Etzioni (1986, 1988) and Lutz (1993) argue that moral behavior cannot be reduced to economic factors.

> . . . people who seek to live up to their moral commitments exhibit systematically and significantly different behavior from people who act to enhance their pleasures. The existence of irreducible moral factors cast doubt about a core assumption of standard choice theory: that people have clear preferences and can 'trade off' relevant items. (Etzioni 1986, p.179)

There is a continuous internal conflict over the degree to which paths OC and OA should be pursued: the paths OA and OC remain irreconcilable.

If moral utility is to be distinguished from pleasure utility, how is it a factor in economic behavior? One example is that savings behavior may be affected by considerations of morality: debt is immoral and one should avoid dependency. Another is that moral commitments reduce moral hazard. "Specifically, *the stronger the moral underwriting of implicit contracts, the lower the administrative costs resulting from less of a need to buy hedge protection...and to spend resources on legal action*" (Etzioni 1986, p.175, author's emphasis). In the case of adopting drip irrigation technology, growers may be sacrificing profits to pursue a social objective of water conservation, or respond to a social constraint imposed by water use rules.

One consequence of acting on the basis of social commitment is that the transactions costs of decision making may increase because "it implies that the stronger the moral commitment, the more likely it will be for people to absorb an economic loss in order to live up to their obligation . . . moral behavior is stickier than amoral behavior" (Etzioni 1986, p.177). This is Hirschman's "tension" and Etzioni's "intrapsychic conflict" that result in increased transactions costs. Although transactions costs may increase, a benefit from acting on the basis of social commitment is a decrease in moral hazard. Thus, while an individual may suffer some economic loss, society as a whole might gain. The relative transactions costs and benefits (reduction in moral hazard) of a particular decision will depend on the specific situation and the degree of moral commitment associated with the choice at hand.

One other argument to support the view that pleasure and moral utility concepts are distinct and not reducible is that many psychologists have argued that pleasures cannot be sublimated into socially approved behavior with full success, that is "moral commitments cannot be exchanged for pleasurable acts without inner and behavioral consequences" (Etzioni 1986, p.179).

If the door is open to inclusion of a moral or social utility, then why should the categories of utilities only be limited to two? Etzioni suggests two reasons for limiting multiple utility to two utilities, or bi-utility. First, there is a pragmatic reason, it is a "matter of what works...One criterion to be used in deciding whether a utility is to be added is whether it *significantly* enriches our predictive and explanatory powers without over determination" (Etzioni 1986, p.171, emphasis mine).

The second reason is that pleasure and morality can be reduced down to two basic categories: Although people are subject to numerous forces, "they experience them as the sum of a limited number of factors" (*ibid*).

To summarize, Etzioni (1986) links Sen's idea of commitment and Hirschman's concept of meta-preference to standard utility theory by arguing that people pursue at least two utilities, pleasure and morality, and that neither one can be reduced into the other. The former reflects the self-interested utility, and the latter reflects the public-interested, or social utility . As noted earlier in following Lynne (1995), OA is the pleasure part and OC is the moral part which is generally irreducible. However, it may be possible paths OA and OC can merge when individual preferences move towards social preferences. Yet, Etzioni (1986, 1988) cautions that self-interested acts (e.g. profit maximization) and moral commitment (e.g. doing what is right for the community) may simply remain incompatible.

An application of these ideas to the subject of irrigation technology adoption means that grower's technology decisions may be influenced by their perception of the social consequences of his/her choice. For example, why do growers invest in modern water conserving irrigation technologies that may not be profitable? Does a meta-preference or a social norm for long-term sustainability affect the grower's decision to adopt? It may be that the answers are "yes", and thus it is relevant to inquire if a grower's decision to adopt drip irrigation is affected by his/her perceived social norms and not assume that profit maximization simply mediates over all human values and goals.

As has been noted, one objective of this research is to investigate the affect of the moral dimension or social norms on the adoption of water conserving technologies. Water conservation is a social issue involving different groups which compete for the use of water. To thoroughly understand the drip technology adoption decision one may need to understand how social norms may affect grower behavior, how growers interact with other groups in the community, and whether growers consider these groups to be important influences in their decisions. Do growers, for example, believe that neighbors, or an environmental group, or a water management district would prefer he/she use a water conserving irrigation system? Is it important to he/she to comply with their wishes? How do growers perception of social norms condition the individual maximization of utility? These questions are investigated in the following chapters.

Control May be Another Influence on Technology Adoption

Johansen has observed that no society is viable without some rules of conduct. Rules are necessary in those cases where strictly economic incentives are absent. This describes the present situation with respect to Florida where an administrative law system of water allocation and use has been established for publicly owned water resources. However, water use rules in Florida may have gone too far.

Control over grower's irrigation technology adoption decisions is reflected in the existence of numerous regulations which virtually micro-manage farming operations. Lynne has noted (1995, p.11-12) that "We can now see why there is considerable discord, especially where the meta-preference is external and is imposed on the farmer. The meta-preference

idea also suggests imposition of more external control could actually lead to less technology adoption", i.e. Florida water regulations could actually become counterproductive.

This could happen because, as Hirschman observes, morality, civic spirit, and trust are important prerequisites to any production activity. However, "disagreement exists over what happens to this 'input' as it is being used" (p.16). Civic duty can be over used to a point where it discourages the pursuit of self-interest. Government can over do regulations. Thus, there is a threshold or limit to influencing and thus achieving socially moral behavior. As Hirschman (p.18) warns, meta-preferences reflected in the public spirit may become scarce "when preached and relied on to excess". Lynne et al. (1995) note that empirical work on Florida strawberry producers behavior suggests that technology mandates, meta-preferences from the outside, may well have been counterproductive, actually creating farmer behavior in rebellion to the dictates of the water management district.

Thus, the supply of such resources as morality, trust, or civic spirit are not fixed or limited like physical factors of production. On the other hand, these same resources can atrophy if they aren't used. Hirschman observes that

> once a social system, such as capitalism, convinces everyone that it can dispense with morality and public spirit, the universal pursuit of self-interest being all that is needed for satisfactory performance, the system will undermine its own viability which is in fact premised on civic behavior and on the respect of certain moral norms to a far greater extent that capitalism's official ideology avows. (p.17)

One goal of this research is to determine if the level of grower control over irrigation technology adoption decisions explains a positive adoption decision.

Empirical Evidence of Multiple Utilities Among Florida Tomato Growers

Tomato growers, like most people, have several objectives that they simultaneously pursue and trade off one against the other. Growers were asked to rank selected objectives, each of which represents a different dimension of choice behavior, and suggesting multiple utilities.

Two categories of objectives were investigated, final objectives and intermediate objectives, for adopters and non-adopters of drip irrigation (Tables 2.1 and 2.2), and for growers located in each of the water management districts (Tables 2.3 and 2.4). Final objectives represent what growers hope to achieve, and therefore reflect latent utilities. Five final objectives include profit maximization, security of access to water for the farm, a high quality natural environment, community recognition, respect, and admiration relative to the farming operation, and independence or free choice in making farming decisions. Profit maximization and water security can be thought of as reflecting the self-interested utility. The high quality of natural environment and community recognition reflect social utility. Independence and free choice represent the grower's objectives with respect to volition. Each grower was asked to allocate 100 points amongst the objectives. If a grower allocated 20 points to each we might say he/she considers each one equally important.

Intermediate objectives are defined as the instrumental means by which final objectives are achieved, so they can be thought of as the way in which the I-utility and the We-utility are achieved. The five intermediate objectives include being self-reliant, being logical and rational in all farming decisions, being in compliance with water use rules and regulations, being capable of managing the irrigation system, and being responsible in the use of water. Being logical and rational in farming decisions and being capable of managing the irrigation and crop system are instrumental objectives designed to maximize the self-interested utility through profit maximization. Being responsible in the use of water and being in compliance with rules and regulations are the instrumental means for satisfying social utility. Finally, being self-reliant reflects the relative importance growers put on their control over their farming operations. Growers allocated 100 points among the five intermediate objectives.

Two major points can be made with respect to Tables 2.1 and 2.2. First, differences in weighing the objectives cannot be explained on the basis of adoption status because there is no correction for the institutional and natural environment that may affect grower weightings. Secondly, the results do suggest the need to at least examine multiple-utility and to consider control as some points were allocated to norms as well as points assigned to being independent.

Grower weightings of intermediate and final objectives can also be shown by water management district (Tables 2.3 and 2.4). Since the three districts (Northwest, Southwest, and South) represent varying degrees of water use regulation, it is important to see if differences exist in the

Table 2.1. Average Ranking of Final Objectives, Adopters and Non-Adopters of Drip Irrigation.

Final Objectives	Non-Adopters	Adopters
Maximize farm profit	24.78	30.90
High quality of natural environment	14.33	17.82
Security of access to water for the farm	24.22	23.70
Community recognition, respect and admiration relative to farming	15.50	11.37[a]
Independence, free choice in farming decisions	21.17	17.02

[a] Adopters differ significantly from non-adopters at a 0.10 probability level.

Table 2.2. Average of Intermediate Objectives, Adopters and Non-Adopters of Drip Irrigation.

Intermediate Objectives	Non-Adopters	Adopters
Being logical, consistent and rational in farming decisions	23.06	22.90
Being capable in managing the irrigation and crop system	17.94	19.01
Being responsible in the use of water	22.78	17.91[a]
Being self-reliant, self-sufficient and independent in farming	24.28	24.90
Being in compliance to rules and regulations	13.06	12.61

[a] Adopters differ significantly from non-adopters at a 0.05 probability level.

degree in grower evaluations of self-interested utility, social utility, and control. The South is the least regulated district, Southwest represents a highly regulated district and Northwest is an intermediate case. Although the South is the least regulated district at the present

time they give a high ranking to security of access to water for the farm. There are two reasons for this. First, farms in the South are bigger and more visible to regulatory personnel and many growers believe they will soon be the target of water restrictions in an area where urbanization is rapidly expanding. Secondly, growers have seen the continuing regulatory trend in the Southwest district and are concerned that they also will be subject to increased water restrictions.

Tables 2.3 and 2.4 do not account for interdependencies between the overlapping "I" and "We" utility curves in Figure 2.1. However, to some extent they show the influence of control across districts upon grower weightings. In the two most controlling districts, Northwest and Southwest, growers want less community recognition and more independence.

Table 2.3 Average Weighing of Final Objectives by Water Management District

Final Objectives	Northwest	Southwest	South
Maximize farm profit	34.28	28.94	20.43
High quality of natural environment	18.92	15.21	17.71
Security of access to water for the farm	19.14	25.06	27.21*
Community recognition, respect and admiration relative to farming	11.22	11.60	16.36
Independence, free choice in farming decisions	21.17	19.90	18.29

* Growers in the South differ significantly from growers in the Northwest at the 0.05 probability level.

In general, there are two important observations to be made concerning the rankings of grower's final and intermediate objectives. The first is that the figures represent "averages" for all groups. There are individuals who gave equal ranking to each objective, just as there were growers who gave zero points to some objectives. Secondly, it is important to note that none of the objectives received a near zero score. The results show that even though social utility (as embodied by community

Table 2.4 Average Weighing of Intermediate Objectives by Water Management District.

Intermediate Objectives	Northwest	Southwest	South
Being logical, consistent and rational in farming decisions	24.19	21.77	23.93
Being capable in managing the irrigation and crop system	16.97	18.23	22.00
Being responsible in the use of water	16.31	20.08[a]	21.43[a]
Being self-reliant, self-sufficient and independent in farming	32.25	22.26[a]	20.50[a]
Being in compliance to rules and regulations	10.28	14.44[a]	12.14

[a] Growers in the South and Southwest differ significantly from growers in the Northwest at the 0.10 probability level.

recognition, high quality of natural environment, and compliance with water use regulations) is not ranked as high as the self-interested utility indicators, the concept of social utility merits investigation because it moderates the level of importance given to self-interested utility goals (profit maximization, security of access to water).

Modelling Multiple Utility and Control

This study uses a specific form of a general group of models called expectancy-value (valence) models to represent the influence of grower self-interest, commitment, and meta-preferences (or a community dimension) over irrigation technology decisions. Decision theorists refer to these as subjective expected utility models. Feather states that

> The terms expectation and expectancy are used interchangeably and they are indexed in terms of the perceived likelihood that an action will be followed by a particular consequence--that is by a subjective probability that the consequence will occur given the response. Similarly, there is a high degree of overlap in the concepts used to refer to the subjective value of the expected consequences. Among the concepts that have been employed are incentive values, utilities, valences, and reinforcement values. (p.1)

There are important reasons for developing a model that reflects the use of expected utility theory. Growers lack complete knowledge about future conditions of what the technology will do, the physical production environment, access to credit, commodity prices and future rules and regulations that affect water use and management. The incorporation of grower beliefs and expectations with respect to technology performance, water resource regulations and allocation mechanisms and social norms captures the essence of a subjective expected multiple utility.

This study applies a variant on the expectancy-valence model used by Lynne, Shonkwiler, and Rola, Hodges et al. and Lynne et al. (1995) to identify the factors that may affect adoption of resource conserving technologies. (See also Feather; Fishbein and Azjen 1975). These models try to address the problem of "the absence of any cohesive conceptual

framework for linking psychological processes and economic decisions" (Lynne, Shonkwiler, and Rola, p.12).

The means to form a multiple-utility economic decision model is suggested by two theoretical concepts of decision making from the field of social psychology: The Theory of Reasoned Action and The Theory of Planned Behavior (Fishbein and Ajzen 1975; Ajzen 1988; Ajzen 1991). The difference between these two theoretical concepts is that the latter adds a component of Perceived Behavioral Control to an Attitude and Social Norm component.

The general model of multiple utility with control takes the form: (2.1)

$$B \sim Intentions = f(\gamma \sum b_i e_i, \beta \sum n_j m_j, \alpha \sum c_k p_k)$$

$$= f(\gamma A, \beta SN, \alpha PBC)$$

where:

B = Behavior or action

Intentions = intention to act (or, in this case, to adopt drip irrigation)

b = belief (probability) about consequences of an action

e = evaluation, utility of the consequence

n = perceived beliefs (probabilities) about social norms of referent groups

m = motivation (utility) from complying with norms of referent groups

c = beliefs (probabilities) about control

p = power to comply

or: $B \sim I = f[\ E\ (U^{I}),\ E\ (U^{We}),\ Control).$

We might also reasonably expect significant interaction among these variables.

The first term, $(b_i e_i)$, reflects the self-interest or individual expected utility $E\ (U^{I})$ as measured by Attitude (A). "A" measures the latent U^{I}. The second term, $(n_j m_j)$ reflects commitment, meta-preferences, moral dimensions, or the community norm $E\ (U^{We})$, or expected We-utility, and is called the Subjective (social) Norm by social psychologists. The last term, $(c_k p_k)$, is Perceived Behavioral Control (PBC) and reflects the extent to which a grower has control (i.e. volition, ability, capital) to make technology choices. PBC can be thought of as reflecting constraints to adoption[1].

More specifically, "b" is the probability scale measuring the degree of belief about whether a consequence will occur, and is implemented by the expectation operator in expected utility $E(U^{I})$. "e" is the utility received if the consequence occurs. Thus, "$b*e$" is measuring the underlying (latent) utility pertaining to the self-interest. The individual components are summed to establish the Attitude (A).

The social norm that represents community influence is composed of "n" grower perceptions of what others believe he/she should do on a

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[1]Examples of the probability and valuative scales for the Attitude and Social Norm variables are found in Chapter IV, and in Chapter V for the Perceived Behavioral Control variable.

probability scale. "m" represents the utility arising from acting on what others believe. We now have expected utility from being influenced by a social norm, a measure of latent, expected social utility, $E(U^{ME})$.

The control term (PBC) addresses three distinct ideas described as volition, ability, and resources or capital available. PBC is viewed as affecting intention (I) and behavior (B) (Ajzen 1988, 1991). The concept accounts for perceptions about the "availability of requisite opportunities and resources" (Ajzen 1991, p.182), which may differ from those factors that are under the actual control (AC) of the grower (Beck and Ajzen, p.287). The rationale for incorporating the Perceived Behavioral Control variable is that growers may perceive that they do not have complete volition in the choices of irrigation technology. Besides capital constraints (financial and human) growers may adopt modern irrigation technologies because they have been forced into it, say, to guarantee renewal of their water use permits. Thus, in addition to knowledge and capital, producer flexibility is constrained by the rules and regulations executed by the water districts.

To solicit information for each of the above components and for measuring the latent utilities a questionnaire was developed which follows a design developed by Ajzen (1988) and Ajzen and Fishbein (1980).

In the Theory of Derived Demand (see Beattie and Taylor), the unconstrained derived demand function for an input to production is:

(2.2) B = f(product prices, technology prices, other input prices)

where behavior (B) represents the amount of the technology installed. For the case where all growers face approximately the same prices for other inputs (fertilizer, fuel, pesticides), the Derived Demand Function becomes:

(2.3) B = f(product prices, technology prices)

Previous research on irrigation technology adoption suggests the need to add environmental variables to the Derived Demand function because these will influence technology prices (Caswell 1991, Caswell and Zilberman 1986). Environmental variables could include climate, soil type, and water quality. Financial and economic variables have previously been found to be important supplements to attitudes in technology adoption modeling (Lynne and Rola; Lynne et al. 1988; and Lynne et al. 1995). The actual physical and economic conditions of growers may not be completely mediated through attitudes toward taking some action, or the degree of control a grower has over irrigation technology choice. There is some concern, then, about not explicitly including a measure of the actual environmental and financial context of the grower.

Inclusion of the context variables gives the modified Derived Demand model:

(2.4) B = f(product prices, technology prices, environmental and financial conditions)

Chapter III shows a test of the Derived Demand model given in equation 2.4. The underlying assumption in this model is that all forces influencing adoption are mediated into one overall utility, i.e first profit maximization which is then used as income to maximize a single, self-interested utility. In effect, testing equation (2.4) in Chapter III is to test mono-utility theory.

Merging Multiple Utility and Derived Demand Models

Chapter IV tests whether adding grower's expected pre-adoption self-interested utility $\{E(U^I)\}$, as measured by (A), and the expected social-utility $\{E(U^{sn})\}$, as measured by (SN), are important to explaining and understanding grower's adoption decisions. This constitutes a test of whether multiple utility theory adds insights about grower's irrigation technology choices.

Equation (2.4) is converted into

(2.5) B = f(product prices, technology prices, environmental and financial conditions, pre-adoption self-interested utility, social norm utility)

Chapter V tests the entire model by adding perceived behavioral control, which represents volition, ability, and further information about financial capability, or

(2.6) B = f(product prices, technology prices, environmental and financial conditions, self-interested utility, social norm utility, control)

Appropriate interaction terms are also added to test for the overlap of the indifference surfaces illustrated in Figure 2.1.

CHAPTER 3
DRIP IRRIGATION TECHNOLOGY ADOPTION IN THE FLORIDA TOMATO INDUSTRY: A NEOCLASSICAL ECONOMICS APPROACH

Introduction

This Chapter's objective is to determine the factors affecting the adoption of drip irrigation technology using a strict version of the neoclassical economics model and to provide preliminary policy interpretations. The analysis corresponds to the self-interested utility component of the multiple utility model. Two econometric models are used to identify factors affecting adoption and results are compared. The first is an Ordinary Least Squares (OLS) model. The dependent variable, y, is the proportion of land in drip irrigation. y is transformed by a logistics function to account for the fact that it can take on values of zero, one, or any fraction in between[1]. The transformed y is similar to the dependent variables of the logit models that are widely used in the water conservation technology adoption literature (Caswell and Zilberman 1986, Dinar and Campbell).

The second model consists a two stage sample-selection model commonly known as the double-hurdle model. This model distinguishes between the factors that influence the initial "yes" or "no" decision to

[1]The dependent variable "y" is transformed by the function w = log (1/yy-1) where yy = propdrip * (propdrip <1) + (propdrip = 1)*.999 and propdrip represents the proportion of farm area in drip irrigation, which can take on values of 0, .999 or any value in between.

adopt, given by the probability of adoption, from those that affect the decision of how much of any particular farm to put into drip irrigation, a measure of the intensity of adoption.

Literature Review[2]

The literature on irrigation technology adoption can be generally classified into normative and positive models of adoption (Caswell 1991). The predominant character of the irrigation technology adoption literature explains adoption as a self-interested, profit maximization strategy, an optimization problem subject to drainage requirements, or both. Profits from adoption are maximized through increased production or product prices and/or decreased production costs. Thus, the economic factors affecting adoption are classified as revenue enhancing or cost minimizing. Following a conceptual model from Caswell and Zilberman (1986) most adoption models have also incorporated selected environmental features such as soil and water quality, well depth, and crop type.

Positive Models

Boggess et al. (1993) indicate that micro irrigation technology has spread quickly in Florida since the 1970's and tends to be adopted in

[2]This section complements existing literature reviews on the factors affecting adoption of modern irrigation technologies (Caswell 1991; Boggess Lacewell and Zilberman; Casey). In addition, the reader should consult surveys that cover the general literature on agricultural technology adoption (e.g. Rogers; Feder Just and Zilberman; Thirtle and Ruttan; Feder and Umali). Major articles that review factors affecting the adoption of soil conservation technologies and management practices include Ervin and Ervin; Nowack; Norris and Batie; Van Es; Lynne Shonkwiler and Rola; Lynne and Rola; and Kalitzandonakes and Monson.

association with high-value fruit and fresh market vegetable crops and in locations of sandy soils, uneven land, and high water costs. "Empirical evidence and numerical simulations suggest that transition to modern technology generally tends to both save water and increase yields. It follows that increases in either output or water prices are likely to increase adoption of modern technologies (Boggess et al. 1993, p.9)". Caswell (1991) suggests input and output prices, decision unit dimensions (field and farm size), human capital, and environmental variables like land quality and weather also affect adoption decisions.

Revenue enhancing factors include increased product prices or augmenting the productive capacity of soil and water resources. Increases in grain prices or transition to crops with higher prices were found to provide incentives for adoption of modern irrigation technology (Casterline et al.; Lichtenberg; Schaible, Kim, and Whittlesey). Several studies have shown that modern irrigation technologies are more likely to be adopted in locations with poor water or soil quality (Feinerman et al.; Caswell and Zilberman, 1985; Letey et al.; Lichtenberg; Dinar and Yaron; Negri and Brooks; Schaible, Kim and Whittlesey; Dinar and Zilberman). Micro irrigation systems can increase the ranges of water quality used in agricultural production. Boggess et al. (1992) and Dinar and Yaron (1990) report that adoption is likely to increase in regions of high temperature and evaporation in order to increase the rate of effective water use. Dinar and Yaron suggest that diffusion of irrigation technologies is affected by water price, crop yield and price, and technology subsidy levels.

Minimization of production costs is another inducement to adopt water conserving irrigation and drainage technologies. For example, it has been found that there is an increased likelihood of adopting drip irrigation as the cost of irrigation water increases (Caswell and Zilberman 1985; Dinar and Yaron). Cost inducement explains why growers using ground water are more likely to adopt modern irrigation technologies than growers using surface water because of higher pumping costs (Caswell and Zilberman 1985). High energy costs to run pumps may also lead to more adoption of low pressure systems (Boggess et al. 1993). Earls and Bernardo state that the feasibility of an irrigation system investment depends on several conditions, including the grower's pumping situation, fuel cost, and the existing irrigation system. They find that the profitability of irrigation system investments is "primarily determined by reductions in irrigation pumping costs attainable from system improvements" (p.23).

Micro irrigation systems can, with proper management, result in more efficient use of fertilizer and pesticides thereby leading to decreased costs. It has been hypothesized that adoption of micro systems is more likely as price of chemicals increase or more precise application is required because of stricter environmental regulations. Nieswiadomy and Negri and Brooks have found that the selection probabilities of irrigation technologies are quite elastic with respect to labor wages.

Grower or "human capital" characteristics associated with adoption of modern irrigation technologies relate to the quality of labor and management. Feder et al. (1985) and Dinar and Yaron state that variables such as age, experience and education significantly affect adoption

levels, although this finding is strongly influenced by the specific human capital variable measured. In some cases, a higher level of experience and skill in managing traditional irrigation systems may diminish the likelihood to adopt modern irrigation technologies (Dinar and Yaron).

Boggess et al. (1993) observe that while static and deterministic models are useful for analyzing seasonal water demand and irrigation technology choices by risk neutral individuals, agricultural activities are inherently risky, and irrigation affects those risks. Boggess and Ritchie show that supplemental irrigation in the Southeast results in a reduction in the overall variance of net returns and thus reduces risk. Irrigation may increase expected yield values, but more often reduces variability in output. In a later study, however, Boggess and Amerling report that even though modern irrigation systems are risk-reducing with respect to yield, investments in systems like drip are in many cases risky:

> Even if prices, costs, financial parameters, and yield responses were known with certainty over the life of the system, uncertainty about the sequence of weather years in humid regions introduces tremendous variability in the net present values of the investment. In effect, the farmer trades a reduction in production risk for an increase in financial risk. (Boggess and Amerling, p. 90)

This finding was supported by Prevatt et al. in a risk return analysis to examine the effect of adopting drip irrigation on expected returns and risk for vegetable farms in southwest Florida. The results of their analysis showed that risk-efficient frontiers for single and double-cropped alternatives under seep irrigated vegetable crops had larger expected returns and smaller risk values than drip irrigated crops. The

major reason for this finding was that the operating capital requirements are larger for drip and some degree of financial risk is taken on.

Although risk is not explicitly modelled in this study, it is accounted for by incorporating subjective expectations about the profitability of drip adoption. The subjective expectations model was described in Chapter II.

Normative Models

Increased social costs from agricultural pollution have been addressed through taxing drainage or inputs, thereby inducing the adoption of water conserving irrigation technologies. Dinar, Knapp, and Letey, Letey et al., and Dinar and Zilberman (1992) found that increased drainage fees are likely to encourage adoption of modern irrigation technology and a reduction in pollution. Wu, Mapp, and Bernardo found that an effluent tax on nitrogen run-off and percolation in the High Plains is effective in reducing nitrate pollution.

Shah, Zilberman, and Chakravorty employed Hotelling's model to investigate the diffusion of drip irrigation systems using exhaustible ground water resources. They show that, under conditions of open access, increasing groundwater depletion should result in higher adoption rates of drip irrigation. The major policy suggestion is that "an optimal resource use tax will accelerate the diffusion of (drip) and slow down excessive resource depletion caused by market failure due to open access conditions" (p. 298, parentheses mine). While this finding is important, access to Florida's groundwater resources are controlled by state water management districts and is not technically open. However, it has only been recently

that applications for agricultural water use permits in some areas of the state have been denied. Thus, until recently, it could be argued that no permit denials virtually meant open access.

Institutional factors affecting adoption include property rights as reflected in land and water tenure conditions, pollution rights, or access to water quotas. Feder et al. (1980) concluded that farmers with secure land tenure rights are more likely to invest in capital technologies to conserve soil. Changes in the legal structure which require compliance with stricter environmental regulations to reduce agricultural pollution can induce adoption of water conserving irrigation systems (Boggess et al. 1993).

A Theoretical Production Model of Irrigation Technology Adoption

Although the research objectives are different in the present study, the theoretical production model used here is similar to a version employed by Dinar and Campbell (1991)[3]. The behavioral assumption in making the decision to adopt drip irrigation is that the grower's goal is to maximize profits, subject to a capital constraint. The profit function is:

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[3]Dinar and Campbell investigated source control of irrigation return flows as a means to reduce high levels of salts and trace elements in drainage water. They hypothesized that a higher rate of adoption is likely to occur when water price is high, when input quality (soil and water) is lower, and when inputs are relatively scarce. They also hypothesized that farm size and organizational structure positively affect the level of adoption, as does the presence of a full time irrigator. In conceptualizing the Florida model, farm structure variables (i.e. farm size, organization, and ownership patterns) and the existence of a full-time irrigator are not included because they are not consistent with derived demand theory. These variables may be conditioned by factors (institutions) that are beyond the complete control of the grower whereas derived demand theory is based solely on physical and economic variables.

(3.1) $\pi = TR - TC = p*(y) - \Sigma(r_n * x_n)$

where TR = total revenue = output price p * quantity of output y

TC = total cost = the sum of the price of the nth input, r * the quantity of the nth input, x.

Dinar and Campbell conceptualize the grower choice problem as selecting the irrigation technology that maximizes profit. Specifically,

(3.2) $MAX_{a\delta} \quad \Sigma_{i=1}^{I} \delta_i *\{ P*f[h(a,i,q,c) i,c] - W*a - V*g(a,i,q,c) - k_i\}$

Where δ_i = a dichotomous variable of 0 if drip technology is not selected, and = 1 if drip is selected, and a = effective water application which represents the design efficiency of the irrigation system. The optimization problem involves a joint discrete-continuous choice where the analysis is conducted in two stages: irrigation system design efficiency, a, is first determined for each irrigation technology, and then profits are compared across technologies.

Dinar and Campbell introduce four components into their profit function: a crop-water production function, an effective irrigation function, a pollution/drainage function, and input and output prices. The crop-water production function which determines output y is specified as:

(3.3) $y = f(e,i,c)$

where:

y = output;

e = effective irrigation: the amount of water used for crop growth;

i = a technology index represented by 0 for the traditional technology and 1 for drip irrigation.

It is assumed that low-volume technologies like drip have the greatest effectiveness, and thus increase output; $f(e, i=1, c) \geq f(e, i=0, c)$;

c = denotes climate as measured in degree days or evaporation.

A high "c" represents higher values for temperature and wind which are assumed to increase yield and evaporation, respectively.

Effective irrigation, e, is determined by the function:

(3.4) $e = h(a,i,q,c)$, where

i and c = as defined above;

a = effective water application and is the actual amount of water applied. It represents irrigation system design efficiency;

q = water quality.

There are three assumptions behind equation (3.4). The first is that high water quality results in higher irrigation effectiveness and thus decreases water costs per unit of output. The second is that more capital intensive irrigation technologies like drip have higher irrigation effectiveness because they can augment water and soil resources as a medium for plant growth. Third, irrigation effectiveness, e, increases with increases in effective water application, a, and favorable climatic conditions, c.

A pollution/drainage function is given by $z = g(x)$, where $g(x) = g(a,i,q,c)$, and all variables are previously defined. Drainage is denoted by run-off or deep percolation. The basic assumptions are that drainage amounts decline with water quality, and increase as more water is applied. It is also assumed that more capital intensive technologies like drip tend to generate less drainage, and therefore less pollution.

Input and output prices include the price of output P, cost of water W, a drainage cost V, and fixed capital costs K. W is represented by the cost of pumping water and K is represented by the capital investment cost of the irrigation system that is independent of the water applied. P,W,V, and K vary with irrigation technology, crop, and physical conditions.

The theoretical production and profit functions for Florida tomato growers is constructed differently. The Florida tomato profit maximization model is given by:

$$(3.5)\quad MAX_{fa} \quad \Sigma^{x}_{i=1}\ \delta_i * \{\ P*f[h(a,i,s,q)\ i] - Wa - K_i\ \}$$

Output, y, remains a function of irrigation effectiveness but now equation (3.4) becomes:

$$(3.6)\quad e = h(a,s,i,q), \text{ where:}$$

i,q, *and* a = as before,

s = soil type.

The climatic, c, variable is not included in the Florida model for two reasons. First, adoption rates are investigated for one crop only, tomatoes. Second, because tomato production takes place year-round under similar temperature, wind and rainfall conditions in each season, the climatic effect on the variability of the marginal revenue product of drip or its adoption rate is considered minimal (Pitts 1995, personal communication).

A soil type variable, s, complements system design efficiency, a, because soil quality is another physical determinant of effective water application in Florida. Soil quality is represented by water holding capacity and determines how much water gets to the plant. Poor soil quality (i.e. sandier soils) result in decreased irrigation efficiency, and higher water costs. It is assumed that the lower the water holding capacity of the soil, the higher the probability that tomato growers will use drip.

Drainage is not included in the Florida model. Most tomato production takes place on fine, sandy soils. Rainfall, surface and ground water used for irrigation easily permeates these soils and penetrates down to the freshwater aquifer quickly. Problems of water pollution associated with run-off from tomato production have not been a concern.

Specification of the Empirical Adoption Model

Adoption of drip irrigation is estimated as a function of economic and physical characteristics of the production environment. On-farm physical environmental conditions are represented by soil and water

quality. Soil quality reflects the farm drainage characteristics (poorly drained, well drained, very well drained) and represents progressively sandier soils. Water quality is measured with a zero-one dummy variable corresponding to the absence or presence of severe water quality problems. It is hypothesized that highly drained soils (i.e. the sandier the soil) will be positively related to the level of adoption. Likewise, the presence of water quality problems will also be positively related to adoption.

A surface water quota constraint, which is used in the California work, is not applicable to the Florida case because large federal and/or state water projects that allocate water for agricultural irrigation do not exist. Although agricultural water quota's do exist in Florida in the sense that growers are permitted, by the state, specific annual quantities for crop production, these amounts are not determined independent of the physical environment or the irrigation systems used. Permitted amounts of water are based on estimates using the Blaney-Criddle model which takes into account weather conditions, soil characteristics, crop type and irrigation efficiency. Thus, permitted amounts are standard across all growers who produce the same crop under similar physical conditions and use the same irrigation technology. Permitted allotments, if included in the Florida adoption model, would result in multi-collinearity problems.

Tomato prices vary by season. Depending on the production location, growers produce for specific market windows and face different seasonal prices. An average nominal 20-year market price is used for tomato farms in regions producing for different market windows. It is hypothesized that growers consider long term average prices when making drip technology

adoption decisions and that adoption is positively related to price. Price is measured in $/24 lb cartons.

There is a differentiation made between whether a farm produces only tomatoes over two seasons or produces tomatoes and then another crop on the same farm. The hypothesis is that growers who grow two tomato crops are more apt to invest in drip irrigation because they can avoid any extra costs associated with re-configuring the system for a different crop. Crop choice is represented by a 0,1 dummy variable with 1 equal to the decision to grow two different crops. Thus, crop choice is assumed to be negatively related to adoption of drip.

Two types of costs are assumed to affect the adoption decision. The major variable cost that differs between adopters and non-adopters of drip is the cost of pumping water. Because detailed data on pumping costs was not obtained, depth-to-water table (in feet) is used as a proxy. It is hypothesized that the greater the depth at which growers must pump, the greater the likelihood of adopting drip irrigation. It is assumed that all growers face similar variable costs for other inputs.

The capital cost of investing in drip irrigation is the second cost variable. For non-adopters, an average investment cost for a drip system is used to represent what the grower would be required to spend if he/she did adopt drip. It is hypothesized that capital investment costs will be negatively related to the probability of adoption. Investment costs are measured in $/acre.

Many irrigation adoption studies are derived from threshold econometric models that show how adopters and non-adopters can be differentiated by a critical level of a heterogeneous characteristic such

as land or water quality. However, Dinar and Campbell note that "previous studies have considered the adoption process at the farm level as a discrete one. This is not necessarily true since at the farm level there are heterogeneous conditions that justify adoption of modern technologies on part of the farm while other parts continue to utilize traditional technologies" (1991, p.13). Their observation holds true for Florida tomato farms. Thus, a logistics function is analyzed using OLS to measure the effect of the identified variables on the proportion of a farm equipped with drip irrigation, given by Y in equation (3.9). The share of drip irrigation is bounded by zero and one, but also has values in between. The derived demand model of drip irrigation technology adoption is given by:

$$(3.7)\quad Y_t = \beta_0 + \beta_1 WQP_t + \beta_2 SOIL_TYP_t + \beta_3 DEPTH_t + \beta_4 COSTAC_t + \beta_5 PRICE_t + \beta_6 CROP_t + \epsilon_t$$

where WPQ and SOIL_TYP represent the presence of water quality problems and soil type, respectively. DEPTH represents pumping costs as proxied by depth to water table, CROP indicates cropping pattern, PRICE is crop price, and COSTAC is the per acre capital investment cost.

Derived Demand Model Results and Interpretation

Tables 3.1 and 3.2 report descriptive statistics and the OLS parameter estimates, respectively, for the variables affecting the proportion of farm shares of drip irrigation technology. All signs on the parameter estimates (Table 3.2) are as hypothesized and all variables are

significant to at least the .05 level. The presence of extremely well drained soils increase the probability of using drip irrigation, supporting the findings of other studies. The parameter sign on CROP indicates that the proportion of farm put into drip irrigation decreases on farms that follow a tomato crop with a different vegetable crop. Although this supports the hypothesis presented earlier, it is only marginally significant given the large number of degrees of freedom.

Table 3.1. Basic Statistics of Dependent Variables and Factors Affecting the Adoption of Drip Irrigation.

Variable	Mean Value	Standard Deviation
DIPADOPT	.70	.46
PROPDRIP	.65	.47
WQP	.23	.43
SOIL_TYP	1.96	.56
CROP	.51	.50
PRICE	6.57	.15
COSTAC	944.82	532.08
DEPTH	459.20	439.62

Tomato price (PRICE) was found to have a positive and very significant influence on the proportion of farm area put into drip irrigation. The capital investment costs of drip have a significant negative influence on the proportion of a farm put into drip irrigation. Increased pumping costs, as proxied by depth to water table (DEPTH), have a positive, but weak influence on the proportion of the farm put into drip irrigation. The results of the Florida analysis generally support the findings of the drip adoption research in California and Israel.

Recall that in these areas it was found that poor soil and water quality, and higher crop and water prices increased the likelihood of adopting water conserving technologies.

Table 3.2. OLS Parameter Estimates for the Derived Demand Model of Drip Irrigation Adoption.

Variable	Parameter Estimates (Standard Errors)
CONSTANT (B_0)	-85.43[a] (15.88)
WQP (B_1)	1.10[b] (.59)
SOIL_TYP (B_2)	1.04[a] (.43)
DEPTH (B_3)	$.13*10^{-2}$[b] ($.78*10^{-3}$)
COSTAC (B_4)	$-.22*10^{-2}$[a] ($.56*10^{-3}$)
PRICE (B_5)	13.58[a] (2.32)
CROP (B_6)	-.75[b] (.49)
R^2	.49
Adjusted R^2	.46
F-Statistic	20.23[a]
Degrees of Freedom	127

a. Significant at the .01 probability level.
b. Significant at the .05 probability level.

High capital investment costs (COSTAC) associated with drip were found to negatively affect adoption, which supports previous predictions by Prevatt et al., Pitts et al., and Pitts and Clark.

A Double-Hurdle Model of Drip Irrigation Adoption

The double-hurdle model conceptualizes irrigation technology adoption as a two-stage decision process. The first stage is a discrete dichotomous choice: "adopt" or "not adopt". The second stage is the level of effort or intensity as measured by proportion of the farm in drip technology, given that drip is used on a specific farm. The double-hurdle model can provide more information by distinguishing between which variables influence the initial decision to adopt from those that are important to the intensity of adoption. A specific form of the model known as the sample-selection method (Heckman's two-step method) is employed (Green).

The double hurdle model has been mostly applied to migration (Nakosteen and Zimmer), labor (Heckman) and consumption decisions. The topic of technology adoption within a utility framework has some commonalities with consumption studies. Growers choose to consume one irrigation technology versus another on the basis of which one will maximize their utility. In double-hurdle consumption decisions, personal perceptions of a product represent the first hurdle to consumption, for example, cigarettes (Jones), shellfish (Lin and Milon), meat (Moon), and food in general (Haines et al.). Cragg "modeled a situation in which the consumer desires a positive amount of the good in question, but consuming the good depends not only on the intensity of that desire but also on such factors as search, information and transaction costs....zero observations may arise either because the desired change is not positive or because other factors inhibit carrying out changes which would be desired in their absence" (Moon, p.28).

Cragg's interpretation as to why there may be zero observations can be applied to modelling drip irrigation adoption behavior. Although a producer may want to adopt drip, adoption does not occur when specific barriers to adoption are high enough. There may be specific physical or economic variables that are important in the initial decision to adopt that are different from those affecting the proportion of the farm in drip irrigation. There are two separate processes determining the zero-one discrete behavior and the level of effort (Blundell and Meghir).

Although application of the double hurdle model is new in the case of technology adoption it's use is justified when one considers the context in which adoption may or may not occur. The context is that most tomato farms are very large and can be characterized by a diversity of soil and water conditions and cropping patterns. Therefore, the decision related to the intensity of use may differ from the initial decision to adopt drip irrigation.

A somewhat similar approach as the double-hurdle was used by Dinar and Campbell. They carried out a two level analysis of adoption behavior. At the first level they analyzed the factors affecting the intensity of drip adoption across all farms cultivated by a single grower using a Tobit procedure. The second level of analysis was to determine the factors that affected a grower's decision to use drip on a particular farm. This second level of analysis was done using a Logit procedure. Different variables were used at each decision level.

The approach used in this dissertation is different from that employed by Dinar and Campbell in two respects. First, the questions being asked here are, one, what motivates tomato growers to adopt drip on

any particular farm (the logit analysis), and two, once that decision is made, what is the intensity of adoption *on that farm* (an OLS analysis). Thus, like food consumption studies that examine consumption decisions by the same individual in two stages, this dissertation examines technology choice by the same individual for the same farm in two stages. The second difference in approach used here from that employed by Dinar and Campbell is that, in most iterations of the model, the same variables are used in each decision stage. This is justified because we are referring to the same unit of analysis, the farm.

The double hurdle model takes the form of:

(3.8)

$$y_i = y_i^* \qquad if \quad y_i^* > 0 \quad , \quad D_i > 0$$
$$= 0 \qquad otherwise$$

$$y_i^* = x_i\beta + e_i$$
$$D_i = z_i\theta + v_i$$

y_i is the observed adoption rate, and y^* is the utility maximizing amount of adoption. D_i characterizes the zero-one discrete decision. X_i is a vector of explanatory variables determining the intensity of adoption, and Z_i is a vector of variables explaining the zero-one decision. The vectors of independent variables(X_i, Z_i) can be the same, or different. In order to compare the relative importance of the variables in each decision stage, all variables are used in both stages of the Derived Demand model. The error terms (e_i, v_i) are assumed to be independently normally distributed with zero means and constant variances.

The model shows that to observe a positive level of adoption two hurdles ($y^* > 0$ and $D_i > 0$) must be overcome. The probability of a zero adoption observation is:

(3.9)

$$\begin{aligned} Pr(y_i = 0) &= Pr(y_i^* = 0) + Pr(y_i^* > 0)\, Pr(D_i = 0) \\ &= 1 - Pr(y_i^* > 0)\, Pr(D_i > 0) \\ &= 1 - Pr(e > -x_i\beta)\, Pr(v > -z_i\theta) \\ &= 1 - F(x_i\beta/\sigma_1)\, F(z_i\theta/\sigma_2) \end{aligned}$$

The first term of the right-hand side of the first line, $Pr(y^* < 0)$, implies that the optimal solution for maximizing utility is not to adopt. The second term, $Pr(y^* > 0)Pr(D_i < 0)$, indicates that non-adoption is due to constraints to adoption. Thus, in the Double-hurdle model the probability of zero adoption is a sum of the two cases.

For the case of adoption, the probability function is:

(3.10)

$$\begin{aligned} Pr(y_i > 0)\, f(y_i \mid y_i^* > 0) &= Pr(D_i > 0)\, Pr(y_i^* > 0)\, f(y_i \mid y_i^* > 0) \\ &= Pr(v > -z_i\theta)\, Pr(e > -x_i\beta)\, f(y_i \mid y_i^* > 0) \\ &= F(x_i\beta/\sigma_1)\, F(z_i\theta/\sigma_2)\, f(y_i - x_i\beta,\ \sigma_1 2)\,/\,F(x_i\beta/\sigma_1) \\ &= F(z_i\theta/\sigma_2)\, f(y_i - x_i\beta,\ \sigma_1) \end{aligned}$$

The log-likelihood function takes the form:

(3.11)

$$\ln L = \sum_0 \ln(1 - F(x_i\beta/\sigma)\, F(z_i\theta/\sigma)) + \sum_1 \ln F(z_i\theta/\sigma) - \sum_1 \ln \frac{1}{\sqrt{2\pi\sigma^2}} - \sum_1 \frac{1}{2\sigma^2}(y_i - x_i\beta)^2$$

The parameter estimates generated by the double-hurdle model for each decision stage, and the marginal effects of each variable on the intensity of adoption, are shown in Table 3.3. All parameters have the expected signs in both stages, with the exception of the positive, but insignificant sign on COSTAC in the second stage. Likewise, the signs on the marginal relationships are as hypothesized. The Inverse Mills Ratio is a selectivity regressor and is used in a regression that tests for sample selectivity as well as the rigor of the estimation technique[4]. The significance of the Ratio indicates that the adopt/not adopt decision is significantly different from the intensity decision, and therefore modelling the decision as a two-stage process is justified.

Rho is a statistic to measure the degree of correlation between the error terms in the two decision stages. The negative coefficient on RHO in Table 3.3 means that there is an inverse relationship between the error terms in each of the decision stages. The significance of Rho is based on a t-test and the result in Table 3.3. lend further evidence to the claim that the two decision stages are different.

In the first stage adopt/not adopt decision, the only significant environmental variable is SOIL_TYP, indicating that the higher the drainage capacity of the soil the greater the probability of adopting drip

[4]For a concise definition of the Inverse Mills Ratio and it's interpretation see Davidson and Mackinnon, pages 544-545.

irrigation. The economic factors of importance include PRICE and COSTAC. PRICE has positive effects on the probability of adoption, and investment cost per acre (COSTAC) a negative effect. Thus, the soil type on any particular farm, the price of tomatoes, and the capital investment costs

Table 3.3. Parameter Estimates for the Double-Hurdle Derived Demand Model of Drip Irrigation Adoption.[1]

Variable	First Stage Decision	Second Stage Decision	$\partial p/\partial x$
CONSTANT (B_0)	-125.46[a] (21.37)	-62.45[a] (.52)	-9.5
WQP (B_1)	.25 (.52)	1.11[b] (.58)	.02
SOIL_TYP (B_2)	.54[a] (.21)	1.27[b] (.64)	.04
DEPTH (B_3)	$.74*10^{-3c}$ ($.48*10^{-3}$)	$.18*10^{-2b}$ ($.90*10^{-3}$)	.00006
COSTAC (B_4)	$-.49*10^{-2a}$ ($.16*10^{-2}$)	$.46*10^{-3}$ ($.50*10^{-3}$)	-.0004
PRICE (B_5)	20.14[a] (3.55)	9.82[a] (2.71)	-.02
CROP (B_6)	-.20 (.49)	-.99[b] (.50)	-.02
MILLS RATIO	-	2.27176[a]	-
RHO	-	-.26[b]	-
LOG LIKELIHOOD	-	-227.41	-
Df	127	127	-

1. Standard errors in parentheses.
a. Significant at the .01 probability level.
b. Significant at the .05 probability level.
c. Significant at the .10 probability level.

associated with drip are the critical variables growers consider in their initial decision to adopt drip irrigation. The results of the Derived

Demand model show that these are the factors that must be addressed in efforts to increase the adoption rate of drip irrigation technology.

Crop price is still quite significant for the proportion of farm area (intensity measure) put into drip irrigation once the decision to adopt has been made. Water quality, soil type, cropping pattern and pumping costs (DEPTH) are also significant, but weak. Pumping costs are more important in the intensity compared to the adopt/not adopt stage and have a positive effect on the proportion of the farm put into drip irrigation. The presence of water quality problems (WQP) and extremely well drained soils have a positive effect on the intensity of adoption. The practice of growing tomatoes and some other crop (CROP) has a negative effect on the intensity of adoption. The larger the farm area that is double cropped with tomatoes and some other vegetable crop, the smaller the area put into drip irrigation. The result that capital investment costs per acre are no longer important in the second decision stage gives evidence that these costs are a more crucial determinant in the initial decision to adopt drip.

Overall, there are two major economic constraints to overcome to increase the probability of drip irrigation adoption: low crop prices and high per acre capital investment costs. Without addressing these, the analysis shows that growers will not adopt drip irrigation.

The dependent variable in the Derived Demand OLS model is the proportion of farm area in drip irrigation, a measure of intensity of adoption, with all the explanatory variables being significant to at least the .05 level (Table 3.2). By contrast, the double-hurdle version of the Derived Demand model distinguishes between those variables which are

critical to the decision to adopt drip irrigation in the first place, and following a positive decision to adopt, which variables are important explanatory factors in the intensity of adoption. It seems that from both a methodological and policy point-of-view that the double-hurdle model is at once more efficient and more informative in explaining grower adoption behavior. Throughout the remainder of this dissertation the double-hurdle model is employed as the vehicle for analyzing adoption behavior.

Simulation Analysis

A simulation analysis is presented to illustrate the sensitivity of the dependent variable in each decision stage to a change in selected independent variables. Only those economic independent variables which are significant to the at least the .01 level are considered. For the probability of adoption these variables are tomato price (PRICE) and the per acre capital investment costs of the irrigation system (COSTAC). For the intensity of adoption only PRICE is considered.

Simulations for each pair of dependent and independent variables are carried-out under the following conditions. Pumping costs (as proxied by DEPTH) are held at their mean value (see Table 3.1). It is also assumed there are no water quality problems and the cropping pattern includes only tomatoes. If PRICE is the simulated variable, then COSTAC is held at its mean value, and vice versa. Each simulation incorporates the three soil types (extremely well drained, well drained, and poorly drained).

Probability of Adoption

Figure 3.1 illustrates the effect of tomato price on the probability of adoption of drip irrigation for each soil type. For all soil types, the probability of adopting drip when tomato prices are below $6.22 per 24 lb. carton is zero. When the price reaches $6.58 per carton, the probability of adoption for all soil types reaches 1. The $.36 per carton differential between a zero and one adoption probability indicates that grower's decisions to adopt drip irrigation are sensitive to relatively small price changes. Higher prices are required to induce growers with poorly drained soils to adopt drip compared to growers with well and extremely well drained soils. The result that the threshold price for any given probability of adoption is lower for farms with extremely well drained and well drained soils makes sense because farms with lower water-holding capacity have more need for the water savings that drip can provide. To compensate for the high investment costs of drip irrigation, growers with poorly drained soils (i.e. greater water-holding capacity) require a higher threshold price for any adoption probability.

Figure 3.2 illustrates the effect of an increase in per acre capital investment costs on the probability of adoption for each soil type. At a cost of $1,100/acre the probability of adoption is one for all soil types and zero at $2,300/acre. At the mid-way point of $1,700/acre, there is a probability of adoption of .25 on poorly drained soils, .45 on well drained soils, and .65 on very well drained soils. In general, for any given capital investment cost, the probability of adoption will be higher on very well drained soils compared with the other soil types. Again,

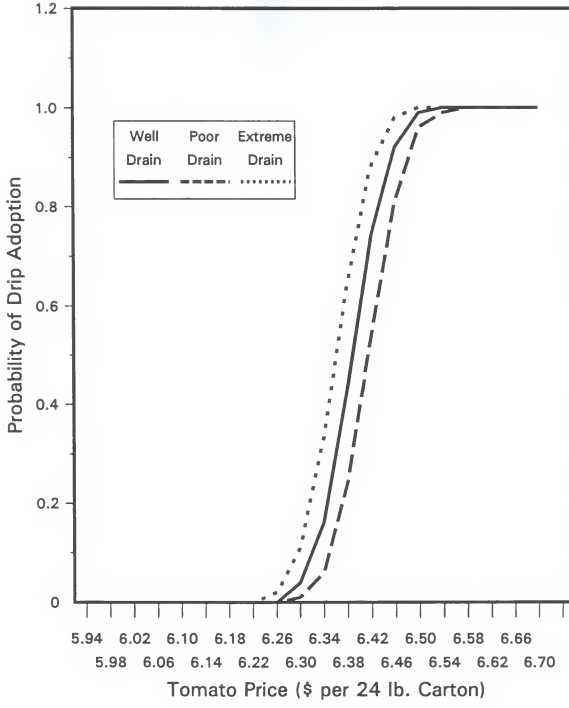

Figure 3.1. Effect of Price on the Probability of Drip Adoption

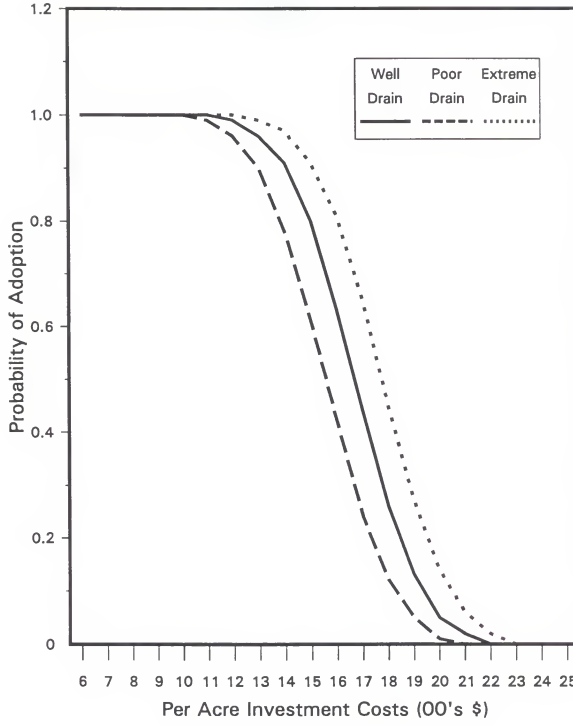

Figure 3.2. Capital Investment Cost Effect on Probability of Drip Adoption

this result makes sense because growers who have difficulties in maintaining soil moisture would be expected to be willing to pay higher investment costs for drip than those who do not.

Intensity of Adoption

Figure 3.3 shows the effect of a change in price on the proportion of farm area put into drip irrigation. For all three soil types, an increase in price induces an increase in farm area under drip. For well and extremely well drained soils it can be seen that prices would have to fall well below the $5.94 per carton level to discourage growers from using drip irrigation. At this price, growers with poorly drained soils would only put about 20% of their farm in drip. Compared to the price effect on the initial decision to adopt drip irrigation (Figure 3.1), the response of the proportion of farm area put into drip to an increase in price is less sensitive. Thus, the price level has a more dramatic effect on the probability of adoption than on the intensity of adoption.

Policy Implications

The policy implications generated by the double-hurdle model versus the OLS model are different in terms of setting priorities to influence the adoption rate of drip irrigation. For example, the results from the OLS model suggest that either a price support, cost-share, or fuel tax program would provide incentives to growers to become first-time adopters of drip irrigation. But which policy is more critical to the adopt/not

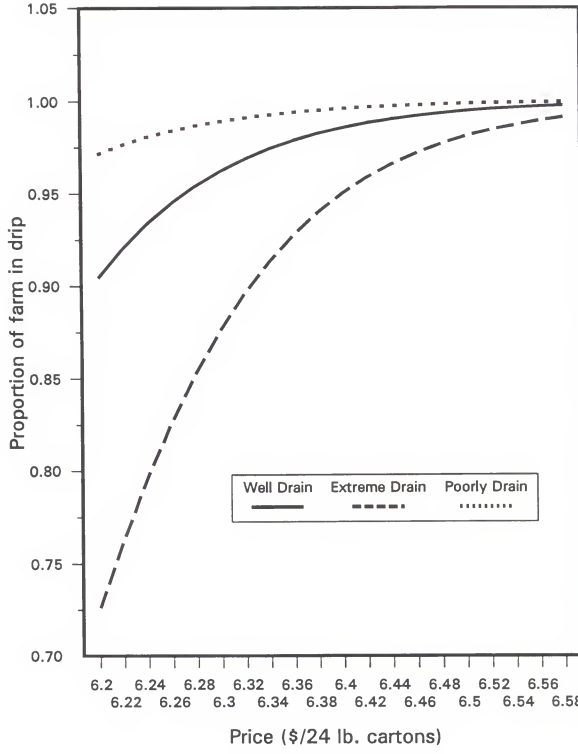

Figure 3.3. Effects of Price on Intensity of Adoption

adopt decision? The double-hurdle conceptualization can provide the answer because it distinguishes between which constraints are important in each decision stage.

According to the results in Table 3.3., all the economic variables act as constraints, to one degree or another, to the initial adopt/not adopt decision. These constraints suggest that a cost-share, price support, and/or fuel tax program could provide incentives to overcome the initial adoption barrier. The simulation analysis showed the probability of adoption is relative more sensitive to a per unit change in price than to per acre capital investment costs, indicating that a price subsidy would be more effective than a cost share program in inducing higher adoption rates for any given soil type. However, because cost share programs may be politically more realistic to achieve, that may be the policy of choice. Any policy intervention, however, would have greater success with those grower's with extremely well drained soils, who represent 69% of the total number of growers. This group may benefit from educational and/or extension activities to encourage adoption of drip in addition to any incentive program.

For adopters of drip irrigation, the interventions for encouraging an increase in the intensity of drip use would be different. A program to cost-share the capital investment costs would not be effective because it is not a significant constraint to increasing the area in drip irrigation. However, a fuel tax would encourage adopters to put a larger share of their farms into drip irrigation, at least in those areas where the water table is high and pumping costs are low, because it would raise the per unit cost of water pumped. The importance of water and soil quality in

the second-stage decision suggests that growers with extremely well drained soils and/or poor water quality would be willing to increase the proportion of their farm in drip if the first stage barriers to adoption were removed.

By distinguishing between the factors important to each stage of the grower's adoption decision, policy interventions to encourage adoption can be better targeted. Furthermore, there is a potential gain in efficiency in the use of public funds to encourage agricultural water conservation through the use of drip irrigation. Based on the results of the double-hurdle Derived Demand model and the simulation analyses, the key incentives to promote adoption would be a cost-share or price support program. If the goal is to increase the area in drip for an individual farm already using drip irrigation, then a fuel tax would be appropriate. Different interventions would apply depending on the extent of drip use on any particular farm. It is also likely that a combination of incentive, education, and research programs would help increase the incidence and intensity of drip irrigation adoption in the Florida tomato industry. However, other policy changes may also be effective. Subsequent chapters in this dissertation apply the double- hurdle model to examine the effect of *ex ante* grower attitudes towards the profitability of drip, grower's community norms, and grower perceptions of control on the decision to adopt drip irrigation technology.

CHAPTER 4
A MULTIPLE UTILITY APPROACH TO EXPLAIN ADOPTION OF DRIP IRRIGATION TECHNOLOGY

Introduction

The research described in Chapter III has resulted in an enhanced ability to explain and to predict grower actions with respect to irrigation technology changes. However, the theoretical structure upon which the analysis in Chapter III is based has been characterized as static, deterministic, and ad hoc (Boggess et al. 1993). Lynne, Shonkwiler, and Rola, Kalaitzandonakes and Boggess, and Lynne et al. (1995) argue that most irrigation adoption literature is ad hoc because there is little behavioral explanation of why some firms are faster to adopt than others. In general, current economic theory is seen as providing limited guidance in the selection of variables to explaining the resource conservation actions of growers (Norris and Batie; Lynne, Shonkwiler, and Rola). For instance, a strict profit maximization framework fails to encompass grower's pre-adoption attitudes towards new technologies, or the degree to which their adoption decisions may be influenced by community norms. A utility maximization framework is less restrictive, but current economic theory in the form of Derived Demand is of little help in identifying psychological processes that determine preferences (Lynne, Shonkwiler, and Rola).

The decision rule to adopt a particular type of irrigation technology appears to be more complicated than the profit maximization motive assumed in Chapter III (Boggess et al. 1993; Hodges et al.; Lynne et al. 1994; Lynne 1995). Other factors, including grower pre-adoption attitudes towards the attributes of new irrigation technologies, risk, or the possibility that growers may also be responding to community influences in their adoption decisions, need to be considered. This chapter addresses the importance of pre-adoption attitudes towards the profitability of drip irrigation and the influence of community on the adoption decision. It tests the multiple-utility approach to explain the adoption of drip irrigation technology.

Almost by definition resource use and resource conserving behavior are social endeavors because individual actions affect others. The decision to adopt water conserving technologies and management practices can be influenced by a grower's perception of what the community at large, and what particular groups that make up that community, might expect him/her to do. It is hypothesized that growers would respond to suggestions and influences from members of various communities with whom they identify. For example, a grower's family might have a significant influence on actions. Outside groups like the water management district or environmental groups may also influence adoption behavior. The community norm as perceived by the grower may well influence adoption behavior. It is the empirical measure of the $E(U^{m})$ component of the multiple-utility function. By incorporating community influences we alter the basic production model presented in Chapter III and move to a multiple-utility conception of the problem.

Literature Review

The importance of preferences, both of a self-interested and social nature, in determining grower behavior is a theme in a number of economic and sociological studies. In turn, preferences are reflected in attitudes and social norms (Azjen and Fishbein 1980; Feather).

Support for including attitudes in a behavioral model has come from Nowack and Korsching (1982) who tested attitudinal variables amongst Iowa farmers and found that risk attitudes have a significant influence on soil conservation decisions. Lynne, Shonkwiler, and Rola, and Lynne and Rola, showed that soil conservation behavior is influenced by grower's attitudes towards conservation and by context variables (e.g. income and farm terrain). They found that soil conservation behavior models can be improved by merging concepts from social psychology and economics. Hodges et al. concluded that strawberry grower's attitudes and social norms significantly affected their adoption decisions of drip irrigation. East has shown that attitudes are important to general investment decisions by individuals. Ervin and Ervin included attitudinal variables in a model of soil conservation decisions, but their empirical results did not indicate that these variables were very important among Missouri farmers. Likewise, Kalaitzandonakes and Monson did not find attitudes important in explaining Missouri farmer's soil conservation decisions.

The Theory of Reasoned Action and the Link to Multiple Utility

The Theory of Reasoned Action is based on an extensive literature of human choice behavior, including traits and attitudes, that has evolved in

the field of social psychology. Ajzen (1988) discusses the trait and the attitude concepts and their role in understanding, explaining, and predicting human actions. Various trait-attitude models have been developed (see Ajzen and Fishbein 1980).

Social norms are the means by which social psychologists assess the importance of such ideas as commitment, meta-preferences, and the moral dimension that are hypothesized to be an important element of human choice behavior. Consistent with Ajzen (1988) and Fishbein and Ajzen (1975) one needs to argue for incorporating grower's community norms in behavioral equations and claim that these norms probably affect behavior. That is, if a grower values what others think should be done, this would influence the grower's behavioral intention and actual behavior with respect to technology adoption.

Expectancy-value models serve as that link between the concepts of attitude, social norm and utility theory. As noted earlier (see p. ?) Feather argues that decision theorists refer to expectancy-value models as a "subjective utility model." In general terms, the expectancy value model is identical to the subjective expected utility model in economics, and represents a way to empirically test the latter.

For the "value" portion of the expectancy-value model, Feather suggests a theory of behavior based on the concept of positive and negative valences held by an individual (p.277). Valence is understood as valuation. Lynne, Shonkwiler, and Rola (p.12) cite Mitchell (p.294) who notes that "the valence of an outcome for a person is defined conceptually as the strength of his positive or negative affective orientation toward it." Valence is therefore an evaluation of the consequence of some

action. Fishbein and Ajzen (1975, p.13) have assumed valence under the concept of attitude, so it seems it describes the farmers' degree of feeling in some particular psychological setting or environment which can be positive or negative in direction. For example, a grower may hold a positive valence (or evaluation) regarding the ability of drip to decrease fuel and electricity for pumping water. However, this positive valence may be offset by a negative valence associated with an expected need to increase labor and management effort. Before making the decision to adopt drip irrigation, a grower makes an internal analysis by weighing the pluses and minuses associated with the decision. An overall positive valence would result in the decision to adopt and the individual would gain more utility.

Lynne et al. (1995) note that the economic notion of utility is closely related to valence, although valence may be a richer concept. The idea of a negative feeling about some action takes on meaning from the possibility of a negative valence, while utility is usually bounded on a qualitative scale from zero to infinite satisfaction. Warshaw and Droge demonstrated that merging utility and attitude models gives an improvement under conditions of non-volitionality. Research by Lynne et al. (1995) has lent support to strong relationship between attitude and expected utility.

An important condition for expectancy-value models to work is the requirement to align action, time, target, and context (Ajzen and Fishbein, 1977). For example, an attitude and an action, "to adopt a drip irrigation system", have to be measured at the same level of specificity. That is, a grower's attitude to adopt drip needs to be measured in

relation to his particular farm or field, not in relation to whether adoption is in general good or bad. Lynne, Shonkwiler, and Rola, Lynne and Rola, and Lynne et al. (1995) found evidence of the need to be careful with specificity.

Using the work by Feather, Ajzen, and Fishbein (all discussed earlier) it is possible to formulate an economic multiple-utility decision model that encompasses both attitudes and community norms as additional motivational factors in technology adoption decisions. Lemon (1973, pp.4-7) provides a version of an integrated conceptual framework which corresponds to equation 2.6, but without the control component:

$$(4.1) \quad B \sim I = f[\, Context,\ Attitudes\ (A),\ Social\ Norm\ (SN)\,]$$

As before, a grower's behavior (B) related to irrigation technology adoption, is reflected in his/her intention (I) to act. Intention is in turn a function of a grower's attitudes (*A*) and perceptions of what others want as reflected in the social, i.e. community, norm (*SN*), and the setting of economic and non-economic institutions and physical factors known as the Context. The Context is reflected in specific farm features, including capital costs of drip irrigation, product price, pumping costs, soil and water quality, and cropping pattern. These are the same variables which were used in the Theory of Derived Demand (Chapter III). Each element contributes to the behavioral intention to adopt drip irrigation technology.

The general model in equation 4.1 is not greatly different from the subjective expected utility (SEU) model in economics. For example, to say

an individual has a strong attitude toward drip irrigation technology is another way of saying that a grower would gain utility from adoption. Thus, the attitude concept is a near kin of the SEU model wherein the probability of the event occurring (belief) is multiplied by the utility (evaluation) of the event giving $E(U^I)$. A parallel argument holds for the social norm variable giving $E(U^{sn})$.

Given the linkage between behavior and utility, a more general multiple utility model that employs psychological, economic, and natural/physical variables can be constructed:

$$(4.2)\quad U = f[\text{Context}, E(U^I), E(U^{sn})]$$

where U is the multiple utility function for adopting drip irrigation.

Empirical Measurement of Latent Utilities Through Attitudes and Social Norms

The work of Ajzen and Fishbein (1977) suggested the design for the tomato grower questionnaire. Bagozzi outlines important considerations in designing the scales and testing for salient properties of the attitude and social norm components of the multiple-utility function (Equation 4.2.).

Measurement of the Latent $E(U^I)$

Fishbein and Ajzen (1975) claim that valence and belief combine to form an attitude, attitude being a measure of the latent expected I-utility. Formally, an attitude is the degree of belief, or probability,

that some consequence will occur, multiplied by the evaluation of the consequences (Fishbein and Ajzen 1975, p. 223).

Recall that attitude concept is empirically measured by a belief and an valuative component, such that:

(4.3)

$$A_j = \sum_{i=1}^{n} b_{ij} \cdot e_{ij}$$

Multiplying the belief score for each subject (b_i) times the valuative statement score (e_i), and summing across all attitude components (n) gives the overall attitude score for subject (A_j), or a measure of $E(U^j)$.

Several belief and valuative components relevant to the attributes of drip irrigation decision were measured in this way for tomato growers. For example, one important belief relative to adopting drip irrigation might be:

A drip irrigation system results in reducing the amount of fuel and electricity used for pumping water

likely _____:_____:__*T*__:_____:_____:_____:_____*unlikely*

extremely quite slightly neither slightly quite extremely

The associated valuative (value) statement is:

Lower fuel, electricity, and other energy use for growing the crop is

important _____:__*T*__:_____:_____:_____:_____:_____*unimportant*

extremely quite slightly neither slightly quite extremely

Assume a grower answered *"slightly likely"* (5 on the probability scale) to the belief statement and *"quite important"* (6 on the valuative scale). The attitude component is then 30 (5 X 6) for this particular dimension. All such dimensions are multiplied and added to form the attitude variable, or $E(U^1)$. Attitude measurements were obtained for both "now" and "then" (denoted by "T" on the scale above). "Then" was defined as *"the period just prior to adoption"*, for adopters and *"about five to ten years ago"* for non-adopters. The analysis of the effects of grower attitudes and social norms on drip irrigation adoption use only the results for the period prior to adoption, or "Then", as we are interested in the antecedent conditions motivating adoption. Given the importance of the decision to invest in drip irrigation it was realistic to assume that growers would remember the factors that influenced their choices.

The series of statements used to solicit grower beliefs about specific attributes of drip irrigation included reducing fuel and electricity for pumping water, fertilizer, pesticides, labor and management, water withdrawn, and pump engine or motor size for irrigation. These are beliefs toward the efficacy of drip irrigation to reduce costs. Statements associated with increasing yield, and improving profit and tomato quality reflect the technology's revenue enhancing effects.

The question arises as to how Attitude, as a measure of $E(U^1)$, is any different from the Context variables (crop price, environment, costs). After all, the Context variables examined in Chapter III are factors directly related to the self-interested behavior of profit maximization. The answer is: the major difference between Attitude and the Context variables is that the former measures grower's *pre-adoption* beliefs and

evaluations of about whether specific attributes of the technology will result in profit maximization. It is a testable hypothesis as to whether or not the addition of pre-adoption attitudes to the Derived Demand model adds further explanatory power.

Measurement of the Latent $E(U^{se})$

The subjective (social or community) norm variable is constructed similarly to the attitude variable by multiplying belief and valuative scores, and summing the component parts.

(4.4)

$$SN_j = \sum_{i=1}^{n} n_{ij} \cdot m_{ij}$$

One belief component of the social norm is:

Other farmers in the area think I should install energy and water conserving technology

likely ___I___:_____:_____:_____:_____:_____:_____unlikely

extremely quite slightly neither slightly quite extremely

A grower might indicate *"extremely likely"* (7 on the belief probability scale), for "then".

The related evaluation asked by *"in general, what these groups think I should do is"* :

Other farmers in the area

important _____:_____:__T__:_____:_____:_____:_____unimportant

extremely quite slightly neither slightly quite extremely

A grower might indicate *"slightly important to me"* (5 on the valuative scale), for "then". This particular component of the subjective (perceived community) norm for "then" is 35 (7 x 5).

Multiplying the two gives the expected utility from being influenced by social norms, and the sum is a measure of the expected latent $E(U^{m})$. The other social or community groups comprising the social norm variable include extension and experiment station, soil conservation service, water management district, and county government personnel, the growers association, homeowners, irrigation equipment dealers, environmental groups and family.

Identifying Salient Attitudes and Social Norms

Bagozzi suggests the possibility that not all the component parts of the attitude and/or social norm variables may be "salient", i.e. adequate indicators of $E(U^{i})$ and $E(U^{m})$, and proposes a method for testing for such saliency. Using the Attitude variable as an example, the method is to use a regression model with a "global" index of grower's attitudes towards drip irrigation as the dependent variable and using the b_i, e_i, and b_i*e_i interaction components as the three right-hand-side explanatory variables.

The global attitude and social norm variables were developed using format recommendations in Ajzen (1988) and Ajzen and Fishbein (1980) and

were evaluated on six 7-point semantic differential scales. Three cognitive and three affective statements were used.

Multiple regressions were run on the global attitude measure as a function of the b_i, e_i, and b_i*e_i components and a component was retained in the I-utility index if the interaction term, b_i*e_i, was significant (see Bagozzi).

For the attitude variable, the regression model takes the form of:

$$(4.5) \quad A_i = \beta_0 + \beta_1 b_i + \beta_2 e_i + \beta_3 b_i*e_i + \epsilon_i$$

The focus is on β_3. If it is significantly different from zero, then this particular attitude represents a salient component of the global attitude (A). The advantage of the Bagozzi approach is that the size of the $\beta 3$ and the R-square is invariant to the selection of scale.

The statistically salient pre-adoption attitudes resulting from the above regression equation, or "Bagozzi" test, were identified as "reducing fuel and electricity for pumping water", "reducing fertilizer applied", "increasing yield", "decreasing production costs", and "improving tomato quality" (Table 4.1). To avoid problems of multi-collinearity with the pumping cost (depth) contextual variable in the derived demand model, the attitude variable towards "reducing fuel and electricity for pumping water" was dropped from the attitude index. Furthermore, "reducing fertilizer" was dropped because of its direct relationship with "decreasing costs of production." Thus, the attitudes remaining in the $E(U^I)$ index include "increasing yield", "improving tomato quality", and "decreasing production costs".

Table 4.1 Results of Regression Analysis for Identifying Salient Grower Attitudes Towards Drip Technology.

Variable	Parameter Estimates (Standard Errors)
Reducing Fuel and Electricity	.31[a] (.07)
Reduction in Fertilizer	.18[a] (.05)
Reduction in Pesticides	.06 (.03)
Reduction in Labor & Management.	.04 (.05)
Reduction in Water Use	.54 (.43)
Decrease Production Costs	.17[b] (.05)
Increase Yield	.15[c] (.06)
Improve Tomato Quality	1.52[c] (.81)
Increase Farm Profit	.59 (.47)
Reducing Engine Size for Irrigation	-.26 (.20)
Improve Water Quality	.04 (.89)

a. Significant at the .01 probability level.
b. Significant at the .05 probability level.
c. Significant at the .10 probability level.

Normally, the salient features of the social norm component of the multiple-utility function would be identified in the same manner as the attitude variable. However, this was not possible because information on a "global community norm" was only solicited from growers in the South and Southwest areas. To include the variable in the adoption equation, all

components of community influence were used in constructing the E(U*) variable. This is not considered a serious problem with respect to the selection of scale and the results of the analysis based on earlier experience (Lynne, Shonkwiler, and Rola).

The Double Hurdle Multiple Utility Model

The multiple utility double hurdle model adds three variables to the Derived Demand model: attitude (A), social (community) norm (SN), and an interaction term (A*SN). The interaction term is designed to capture the effect of any interrelationship there might be between a grower's attitude and perception of community influence towards the drip adoption decision. The multiple utility version of the adoption model thus takes the following form:

$$(4.6) \quad B \sim I = f\,[Context,\ A,\ SN]$$

where the Context is defined as the set of previously defined environmental and economic variables used in the Theory of Derived Demand from Chapter III. Adoption behavior (B) and intention (I) are modelled as a two stage decision process: the initial decision to adopt drip irrigation followed by the intensity of adoption. As in Chapter III, intensity is measured by the proportion of the farm put into drip irrigation.

The empirical specification of the multiple utility model does not use all of the variables in both stages of the drip adoption decision.

Specifically, the social norm variable and the interaction term (A*SN) are not included in the second stage. It is assumed that the social norm would only be important in the grower's initial decision to adopt or not adopt drip irrigation, whereas the intensity of adoption is governed by environmental and economic contextual factors and grower's pre-adoption attitudes towards the profitability of drip irrigation.

Empirical Results and Analysis

Table 4.2 gives the results of the double-hurdle adoption model where grower's pre-adoption attitudes are added to the contextual variables of the Derived Demand model. The significance of the Inverse Mills Ratio indicates that there is a definite difference between the two decision processes (the yes/no decision and the intensity decision). All signs in each decision stage are as hypothesized.

The addition of attitudes to the Derived Demand model causes virtually no change in the levels or significance of the production parameters calculated in Chapter III[1] (see Table 3.3). Grower's pre-adoption attitudes towards the profitability of drip are not significant in either decision stage. A log likelihood test gives a chi-square .788 with 1 degree of freedom (df) which is not significant and indicates that the addition of pre-adoption attitudes alone does nothing to increase the explanatory power of the adoption model. This result is not entirely surprising for two reasons. First, pre-adoption attitudes represent the profitability of drip and may be measuring the same influence as

[1] For this reason no simulation analysis is offered for this section.

Table 4.2. Parameter Estimates for the Double-Hurdle Derived Demand Model With Attitudes for Drip Irrigation Adoption[1].

Variable	First Stage Decision	Second Stage Decision	$\partial p/\partial x$
CONSTANT (B_0)	-126.39[a] (21.64)	-58.71[a] (17.89)	-9.5
WQP (B_1)	.28 (.54)	1.03[b] (.58)	.02
SOIL_TYP (B_2)	.54[a] (.21)	1.17[b] (.63)	.04
DEPTH (B_3)	$.72*10^{-3c}$ ($.47*10^{-3}$)	$.18*10^{-2b}$ ($.91*10^{-3}$)	.00008
COSTAC (B_4)	$-.49*10^{-2a}$ ($.16*10^{-2}$)	$.50*10^{-3}$ ($.49*10^{-3}$)	-.0003
PRICE (B_5)	20.30[a] (3.57)	9.11[a] (2.71)	1.52
CROP (B_6)	-.19 (.49)	-.87[b] (.53)	-.01
ATTDRIPT (B_7)	$-.12*10^{-2}$ ($.69*10^{-2}$)	.01 (.01)	.00008
MILLS RATIO	-	2.26696[a] (.21)	-
RHO	-	-.29[b] (.14)	-
LOG LIKELIHOOD	-	-227.02	-
Df	126	126	-

1. Standard errors in parentheses.
a. Significant at the .01 probability level.
b. Significant at the .05 probability level.
c. Significant at the .10 probability level.

contextual physical and economic variables. Recall that the results of the "Baggozi test" indicated that decreased production costs, increased yields, and increased tomato quality were the "salient" components of the attitude variable. Thus, growers pre-adoption attitudes reflect what the

physical and economic variables in the Derived Demand model are also meant to measure: profitability.

Table 4.3 shows the results of multiple-utility model where the social norm and interaction terms are added to the Derived Demand model with attitudes. Again, the significance of the Inverse Mills Ratio continues to provide evidence that the drip irrigation adoption decision is a two stage process.

In comparison with the results in Table 4.2., the multiple utility model results show that water quality is still a significant factor determining the area of farm put into drip irrigation. Soil type also continues to be a significant determining factor in both decision stages, indicating that the more well drained the soil is the greater the probability of and intensity of adoption. Even with the addition of the social norm variable these results continue to be consistent with previous research findings on micro-irrigation adoption.

The economic contextual variables of PRICE and COSTAC continue to be very significant in explaining the initial decision to adopt drip irrigation. Crop price is also quite important in grower's decisions concerning the proportion of the farm to put into drip irrigation. These results parallel those of the Derived Demand model in Chapter III.

Pumping costs (DEPTH) are highly significant in the intensity stage of adoption, but are no longer important in the initial decision to adopt. Cropping pattern is now only slightly significant in the second decision stage of the multiple-utility model, showing a weaker effect compared to the Derived Demand model.

With the inclusion of the social norm variable, pre-adoption

Table 4.3. Parameter Estimates for the Double-Hurdle Multiple Multiple Utility Model[1].

Variable	First Stage Decision	Second Stage Decision	$\partial p/\partial x$
CONSTANT (B_0)	-113.93[a] (24.95)	-57.63[a] (18.00)	-7.89
WQP (B_1)	.56 (.54)	.99[b] (.58)	.04
SOIL_TYP (B_2)	.42[b] (.24)	1.13[b] (.63)	.03
DEPTH (B_3)	$.36*10^{-3}$ ($.52*10^{-3}$)	$.21*10^{-2a}$ ($.88*10^{-3}$)	.00002
COSTAC (B_4)	$-.57*10^{-2a}$ ($.13*10^{-2}$)	$.30*10^{-3}$ ($.49*10^{-3}$)	-.0004
PRICE (B_5)	18.39[a] (3.96)	8.90[a] (2.72)	1.27
CROP (B_6)	-.06 (.45)	-.69[c] (.51)	-.004
ATTDRIPT (B_7) (A)	.03[b] (.01)	.02 (.01)	.0002
SOCIAL NORM (B_8) (SN)	$.20*10^{-2}$ ($.44*10^{-2}$)	-	.0001
A*SN (B_9)	$-.97*10^{-4c}$ ($.64*10^{-4}$)	-	$-6.74*10^{-6}$
MILLS RATIO	-	2.19283[a] (.22)	-
RHO	-	-.42[b] (.19)	-
LOG LIKELIHOOD	-	-227.98	-
Df	124	-	-

1. Standard errors in parentheses.
a. Significant at the .01 probability level.
b. Significant at the .05 probability level.
c. Significant at the .10 probability level.

attitudes become significant in the first stage adopt/not adopt decision.

This suggests that one may only be able to understand the effects of pursuing self-interest, as reflected in Attitudes as a measure of latent $E[U^i]$,) within the context of the individual pursuing his/her social norm as a measure of latent $E[U^m]$. The significance of the Attitude variable here suggests that pre-adoption attitudes gain meaning only in the social context in which production takes place. That is, there is an overlap between $E(U^i)$ and $E(U^m)$ as depicted in Figure 2.1.

Social Norms have a positive, but not a significant, effect on the probability of adoption, as long as self-interested attitudes are not too strong. The derivative $\partial y/\partial SN = \beta_8 - .97 \times 10^{-4}A$ shows that the stronger the self-interest Attitude variable, the weaker the influence of the social norm, where y represents the first stage adoption decision. The indifference sets overlap and the stronger self-interest dampens the effect of the social norm, and vice versus.

Similarly, the negative sign on the interaction term also indicates that the social norm has a negative effect over the influence of the attitude variable on the initial adoption decision. As attitudes intensify, the effect of $\partial y/\partial A = \beta_7 - .97 \times 10^{-4}$ SN will become smaller as SN increases. Thus, as a grower's social norm increases, there is an offset against the self-interest attitude. Recalling that grower's pre-adoption attitudes measure the grower's perception of the profitability of drip irrigation, this result gives empirical evidence that when social norms are considered, an individual may move from a point like A in Figure 2.1 towards point C.

To summarize, the results from the multiple utility double-hurdle model support the findings of the Derived Demand model (with and without

the attitude variable), but adds more power in explaining the initial adopt/not adopt decision. The addition of the attitude variable ($E[U^{i}]$) in conjunction with the social norm variable ($E[U^{**}]$), increases the explanatory power to derived demand model for two reasons. First, all of the contextual variables that were significant in the Derived Demand model (See Table 3.2) continue to be so under the theory of multiple utility. Second, a Chi-square test shows that the multiple utility double-hurdle model of adoption behavior has more explanatory power than the Derived Demand models with and without the attitude variable. In comparing the multiple utility model with the Derived Demand model with attitudes, the test gives a χ^2 of 19.77 with 3 df's, which is significant at the .005 level. The significance of the chi-square statistic suggests that substantial specification error would occur if only the contextual economic and physical variables and pre-adoption attitudes were used. This result indicates that the terms $E[U^{i}]$ and $E[U^{**}]$, which form the basis of the multiple utility concept, gives a model that has significantly more power in explaining grower drip irrigation adoption behavior than the Theory of Derived Demand.

Theoretical and Policy Implications

There are two important theoretical and policy implications that can be derived from the results shown in Table 4.3. On a theoretical level, it is shown that grower's pre-adoption attitudes that reflect self-interested I-utility are important in explaining the initial decision to adopt drip irrigation. This lends support to the assumption of profit maximization under the Derived Demand model, but it also indicates that a

more complicated behavioral response on the part of growers to the adoption of new irrigation technologies. Purely environmental and economic contextual factors are alone not sufficient to explain adoption behavior. Grower's expectations or beliefs about what drip irrigation will do, and the value that grower's assign to these expectations or beliefs, are equally important in examining adoption behavior. Despite the production and economic benefits of drip that research and extension might show, grower's attitudes matter. Grower's attitudes towards the profitability of drip may or may not be positive given the conditions under which a particular individual farms, information sources, and experience. Nonetheless, the positive sign and the significance of attitudes of the probability of adoption provides a "behavioral" explanation of why some growers may be faster to adopt than others.

Two neo-classical variables, crop price and per acre capital investment costs, remain important in the first stage of adoption in the multiple utility double-hurdle model, indicating that a price support or technology cost sharing program could continue to provide incentives to increase the incidence of drip irrigation adoption. Pumping costs are important in the intensity of adoption, suggesting that a fuel tax could result in more farm land being put into drip irrigation. However, the significance of the attitude variable suggests another policy intervention that may be as important as purely economic incentives. Specifically, more effort expended on research and extension to influence grower's pre-adoption attitudes towards drip irrigation attributes could result in increased rates of adoption.

CHAPTER 5
THE MULTIPLE UTILITY MODEL WITH CONTROL

Introduction

This Chapter further tests the theory of multiple utility by adding the effects of grower volition and control in drip irrigation adoption. Inferences can then be made with respect to the way regulation may affect grower's adoption decisions. The question under discussion is whether regulation, and it's effect in decreasing grower volition in irrigation technology choice, positively or negatively affects drip irrigation adoption. The hypothesis suggested here is that the more volition growers perceive they have, i.e. the lower the perceived level of regulation over technology choice, the more likely growers are to adopt drip irrigation, and adopt it more intensively, at least after a certain threshold is reached.

A major supposition of economic theory is that producers can freely substitute inputs in order to maximize technical efficiency and income. In reality, however, no producer exercises complete volition over the inputs he/she uses in the production process. Growers face several types of constraints to free input substitution including, but not limited to, the availability of capital and the knowledge to efficiently use certain kinds of inputs. Drip irrigation is both expensive and difficult to efficiently manage.

While the concepts of ability and financial control are constraints that have been addressed widely in the technology adoption literature (Feder, Just and Zilberman 1985; Caswell 1991; Boggess et al. 1993; Feder and Umali 1993.) the effect of regulation on technology adoption, and its implicit relationship to the concept of volition, has received less attention. At the outset, then, it is necessary to explain the linkage between the regulatory environment concerning agricultural water use, volition, and the drip irrigation technology adoption decision.

The agricultural technology adoption literature has historically assumed that farmers are voluntaristic decision makers (van Es 1982; Nowack 1982), i.e. farmers have virtually full volition over the decision to adopt agricultural technology. This was probably a fair assumption when there were fewer regulations affecting grower's technology decisions. Furthermore, the "full volition" assumption supports the neoclassical economic paradigm, which assumes no impediments on the farmer to choose technologies except for cost/capital constraints (Feder and Umali 1993).

In the past, agricultural technology policy in Florida focused on university based extension education and demonstrations in joint partnership with the private sector. Grower associations encouraged good practices while Federal agencies provided technical assistance and cost sharing. There was little regulation. A turning point came in Florida in the early 1970's when Floridians passed progressive environmental legislation. Florida put in place an administrative system for implementing a top down, some have called it a "micromanagement", approach to agricultural water use.

In Florida, water is essentially a publicly owned good. The 1972 Water Resources Act authorizes the states' five water management districts to establish a water use permitting process which gives individuals qualified use rights to state-owned water. There are two essential elements of this allocation process. First, a particular use must be shown to be reasonable and beneficial. Second, the state's Water Management Districts (WMD's) have the authority to define and enforce rules and regulations designed to fulfil water conservation objectives of the 1972 Act. To promote the state's water conservation goals, WMD's set crop-specific water quota's and can mandate irrigation efficiency standards. Irrigation efficiency standards of 80%, compared to 50-60% in practice, have been set. In reality, the increased efficiency standards dictate what technology can be used in order to receive or renew a water use permit. Under current conditions, the 80% standard can only be met with the use of drip irrigation.

Water management district personnel are given authority to force compliance with technology standards. The major policy instrument to ensure that technological standards are met is the Consumptive Use Permit. In principle, if a grower does not meet a technical efficiency standard his/her permit can be revoked. With more state concern over water use, Florida growers are subjected to more scrutiny and control by the state's water management districts.

Florida's regulatory system illustrates that the standard assumption of free choice (i.e. full volition) with respect to technology adoption is not an adequate representation of reality. Producer flexibility with respect to technology choice and water use is constrained by rules and

regulations executed by the water management districts. The regulatory nature of water use rights through permitting procedures and producer liability for externalities resulting from irrigation are institutional conditions that directly affect farmer choices of technology.

Literature Review

There is currently a debate over the effects of environmental regulations on technology adoption and innovation. Some researchers claim that regulatory requirements discourage adoption and/or efficient uses of new technologies, primarily through input price distortions. Others theorize that regulation can spur innovation and adoption of new technologies, and can increase competitiveness. Research findings representing both viewpoints are summarized.

Abler and Shorter (as cited by Bosch et al.) have identified four general strategies to protect water quality which are equally applicable to water conservation: (1) moral suasion and education; (2) direct regulation; (3) economic incentives; and (4) research and development.

> Moral suasion and education are based on the premise that growers will voluntarily adopt practices if they are fully informed about the economic and environmental consequences of their current water use practices. Direct regulation can be implemented through either design standards (regulating the way growers manage their resources) or performance standards (regulating the quantity of water used in production). Economic incentives may include taxes on water use or subsidies to defray the costs of more efficient irrigation technologies. A long term strategy for reducing water use is to encourage research and development of alternative irrigation technologies and water management practices. (Bosch et al., p.14)

Policy tools to promote voluntary adoption include extension education, technical assistance, and cost sharing. In Florida, public policies to conserve water have relied primarily on the second type of instrument, direct regulation through performance standards.

Regulations Inhibit Adoption

Bosch et al. recently investigated the relative effectiveness of regulatory and incentive (volitional) approaches on the adoption of soil nitrogen testing to improve water quality. They found that "while the immediate goal of adoption may be more easily achieved by regulation, regulation will not necessarily lead to the proper or desired use of the practice" (p.37). Their results also show that while regulation leads to higher levels of adoption, it does not have an "educational" effect on adopters. The authors concluded that regulation to enforce adoption of nitrogen testing may not induce the desired behavioral changes needed to improve water quality. Growers may comply with the regulation without changing water use practices because they lack information on the benefits of such practices. Thus, in the Florida context, adoption of drip irrigation may not result in attainment of the desired efficiency levels if grower's don't know how to manage drip irrigation effectively.

Teague, Bernardo, and Mapp investigated whether voluntary management approaches of protecting ground water quality were more efficient than regulation. Management-based (voluntary) policy options are associated with freedom of producer choice as a key concept and include performance standards, economic incentives, and research and development. Although performance standards are a form of regulation, the emphasis is upon

allowing producers to freely choose among production alternatives. Research and development is aimed at enhancing the choice set. The authors compared regulatory and management-based approaches and showed that management-based means that allow producers maximum discretion in reaching environmental goals are the most effective.

Wu et al. used a dynamic model to analyze growers irrigation investment and crop choice decisions under four alternatives and investigated the effects of these policies on farm income, crop yield, water use, run-off and percolation. The choices included three incentive policies consisting of a cost-sharing for modern irrigation technology, drainage charges, and taxes on nitrogen application. There was also one regulatory policy represented by restricting irrigation water use. The authors found that cost sharing can reduce water use by inducing the adoption of modern irrigation technologies. However, if the percentage of the fixed cost shared is not set high enough, the policy is completely ineffective. (This observation would also describe the Florida case where a drip irrigation cost share program of $3000 per farm does not come close to matching capital investment costs which average over $1000 per acre). A drainage tax was found to be very effective in reducing water use and nitrogen pollution and inducing the adoption of modern irrigation technologies. A tax on nitrogen fertilizer was less effective.

Wu et al. concluded that while "moderate" restrictions on irrigation water use would encourage adoption of modern irrigation technologies, "excessive" restrictions would discourage their use. This is due to the fact that when modern systems are used to pump a limited amount of water, the gain from the increased application efficiency can not compensate for

the increased irrigation fixed cost. Thus, caution must be exercised in setting limits on water use to induce technology adoption.

The impacts of the above described policies on farm income and water use will differ according to the desired objectives. If the objective is to conserve water and reduce drainage, water use restrictions or a tax on nitrogen run-off and percolation may be preferred. If the objective is to promote the adoption of modern irrigation systems, and at the same time maintain farmers income, the cost sharing policy may be the best choice. Wu et al. suggest that priority should be given to those policies which encourage the adoption of modern irrigation technologies. Public research aimed at improving the design and reducing the fixed cost of the modern systems would also be worthwhile.

Ajzen and Driver (1992) and Beck and Ajzen (1991) have noted that accounting for perceived behavioral control improves prediction of actual behavior. In an application of a multiple utility model with control to the Florida strawberry industry, Lynne et al. (1995) found that the significance of perceived behavioral control (including volition) verified a situation in which there was something less than full volition, but more than constrained volition in the choice of irrigation technologies. Their findings suggest that a higher degree of grower volition in the choice of drip irrigation results in an increased rate of adoption and conclude that there should be fewer controls on grower choices while providing more incentives to participate in water conservation programs.

Regulation as a Stimulus to Innovation and Technology Adoption

In contrast to the negative effects that regulatory, or non-voluntary, programs have been found to have on technology adoption, another literature argues that regulation occurring under specific conditions can increase the adoption of environmentally desirable technologies and increase firm competitiveness. The main proponents of this view include Porter and van der Linde.

The central message of this recent literature is that the environment-competitiveness debate has been incorrectly framed.

> By focusing on the static cost impacts of environmental regulation, while ignoring the more dynamic impacts, policy makers, businesses, and environmentalists have unnecessarily driven up costs and slowed progress on environmental issues. (Porter and van der Linde, p.11)

In this new paradigm, *innovation* provides a way to minimize the costs of addressing environmental regulations while delivering other competitive benefits. These competitive benefits exist in the form of "innovation offsets". Strict environmental regulations can, by stimulating innovation, actually enhance competitiveness. Thus, the focus should be on creating the conditions most conducive to innovation in setting and implementing environmental standards.

Porter and van der Linde note that the environmental-competitiveness relationship has normally been thought of as a tradeoff. On one side are the "social" benefits, such as water conservation, that arise from strict environmental standards, illustrated by water use restrictions or technology mandates. However, there are others who argue that the U.S.

has overshot in setting standards where the incremental benefits are dubious. There is also the distributional question in asking "benefits for "whom" in society?

On the other side of the trade-off are costs in terms of high prices and reduced industry competitiveness from too much regulation. The idea here is that obtaining social environmental benefits involves private costs. For example, the tomato industry bears the costs of being forced to adopt drip irrigation. To get the social benefits, a nation or region must necessarily bear proportional private costs. The issue thus becomes the appropriate balance between environmental protection and the economic burden on industry. Framed this way, environmental improvement or water conservation becomes a distributional power struggle. There are two sides, agriculture and the water management districts, with diametrically opposed objectives. The struggle involves what standards will be imposed and who will pay. The struggle also induces high transactions costs in the form of debating, administrating, enforcing and perhaps fighting regulations.

Porter and van der Linde stress that rather than assuming an inherent, fixed tradeoff between the environment and competitiveness, the focus should be on how we can relax the tradeoff as much as possible and perhaps even eliminate it, by creating countervailing benefits through innovations to address regulations. This is the dynamic view of regulation which stresses the point that competition is anything but static.

> In dynamic competition firms can respond to environmental regulation, or even anticipate it, with innovation. Properly

> designed environmental standards can trigger innovation that may offset the costs of compliance-what we term innovation offsets. (Porter and van der Linde, p. 14)

Innovation offsets may not only lower the net cost of meeting environmental regulations but also lead to absolute advantages over other firms. Examples of innovation offsets coming from a regulation to use drip irrigation may be the adoption of new cropping or water management techniques resulting in increased tomato yields and/or quality. These benefits, however, are also critically important on the quality of irrigation system management. Drip irrigation was pioneered and developed in Israel where low water quotas forced agricultural producers to seek water-saving technologies. Israel is now the biggest manufacturer of drip irrigation equipment in the world, even exporting to the United States where Florida tomato producers use their equipment. Thus, the original quantitative restriction on agricultural water use in Israel has led to an absolute advantage in marketing drip technology.

One of the criticisms of the Porter and van der Linde argument is that if innovation to deal with environmental regulation is so profitable, why is regulation even necessary? That is, if profit opportunities existed, why haven't all growers adopted drip irrigation without regulations? Porter and van der Linde offer the following explanation for why regulation is necessary. First, some firms do pursue the adoption of drip without or even in advance of regulations. This is the case with tomato producer adoption of drip irrigation in northern Florida. But,

> . . . lying behind the criticism is a deeper issue: the prevailing analytical approach consists of a static optimization framework in which information is assumed to be

> perfect, profitable opportunities for innovation or adoption have already been discovered, and profit maximization will lead to rapid adoption worthwhile technologies. However, these assumptions don't describe reality. (Porter and van der Linde, p.33-35)

Research by Porter and van der Linde suggest that dynamic competition is governed by highly incomplete information, limits on firm attention, organizational inertia, and control problems reflecting the difficulty in aligning individual group and corporate incentives. Environmental regulations are needed for four major reasons: to signal firms about potential technological improvements; to reduce uncertainty about the demand for solutions to environmental problems; to create pressure as a motivator for overcoming organizational inertia and fostering creative thinking; and lastly, to fill a gap where there is an incomplete offset, especially until learning effects reduce the cost of innovation-based solutions.

For regulations to actually foster innovation offsets, three criteria must be met (Porter and van der Linde). First, regulations must create the maximum opportunity for innovation, leaving the approach to innovation to the industry and not to standard-setting agencies. This would imply that regulations which set performance standards that can be met with only one type of technology must give way to more general water conservation goals.

The second criteria is that regulations should foster continuous improvement, rather than locking in a technology or merely freezing the status quo. Clearly, setting a water use efficiency level that can only be attained through the use of drip irrigation is a regulation that "locks

in" and limits grower's irrigation technology decisions. Criteria one and two are means by which volition is increased.

Third, there should be as little room for uncertainty at any stage in the regulatory process as possible. For example, if grower's are uncertain about what the content of water use regulations will be, or believe they can be delayed or modified, investments to address environmental impacts will be withheld. According to tomato growers, a major problem of water use regulations in general, and specific regulations related to technology use in particular, is the high degree of uncertainty as to what is required. There are three sources of uncertainty. First, water use and technology regulations result from what is essentially a political process fraught with uncertain outcomes. Outcomes are uncertain because the administrative process of selecting and mandating technologies or management practices involves dynamic negotiation and compromise.

Second, there are frequent changes in water use regulations and standards. Porter and van der Linde have noted that regulated firms may be reluctant to innovate or to adopt more efficient technologies if they anticipate that any resulting gains in the efficiency of water use will lead to subsequent tightening of regulatory standards. Many tomato growers believe that adoption of drip irrigation will result in a decrease in the amount of water allocated to them by the WMD's.

Third, there are differences in the interpretation and enforcement of given regulations, resulting in high transactions costs.

More fundamentally, the most important single barrier to innovation-promoting regulation is the prevailing mind set:

> As long as the constituencies involved see environmental regulation as a fundamentally adversarial, win-or-lose proposition, innovative solutions will often not even be considered.(Porter and van der Linde, p.36)

In this case, growers may not even attempt to experiment with drip irrigation if they perceive the water management district as "the enemy" trying to control their farm decisions.

The Theory of Multiple Utility With Control

The expectancy-value model with control adds perceived behavioral control (Azjen 1988). Perceived behavioral control is viewed as affecting both the intention (I) and behavior (B) (Azjen 1988, 1991) to adopt drip irrigation technology. The concept accounts for perceptions about the "availability of requisite opportunities and resources" (Azjen 1991, p.182) which may differ from the context (i.e. environmental conditions, costs, prices) in which the adoption decision is made.

The addition of perceived behavioral control recognizes there is a continuum that runs from total control and full volition to a complete lack of control and no volition. The theory suggests there may be an intermediate point for many behaviors (Godin et al., p.82). Ajzen (1991, p. 181) added perceived behavioral control to the Reasoned Action model to overcome the limitation of "dealing with behaviors over which people have incomplete volitional control" due, for example, to abilities, available financial resources, or to regulatory controls. "Control" includes volition as compared to something less than full volition. The focus here is on whether a grower has control over the decision to buy a drip system.

Whether control in the volitional sense needs to be considered becomes a testable, empirical issue.

With the addition of control, and the interaction terms, the multiple utility model takes the form:

$$(5.1)\quad B \sim I = \beta_0 + \beta_1 (A) + \beta_2 (SN) + \beta_3 (PBC) + \beta_4 (A*SN) + \beta_5 (A*PBC) + \beta_6 (SN*PBC) + \beta_7 (A*SN*PBC) + \beta_8 (Context\ Variables) + \epsilon\ (A*SN*PBC)$$

From equation 5.1. it is hypothesized that β_3 will be significantly > 0 in the first stage of the adoption decision, i.e., the more control a grower has (including more volition), the higher the probability of being an adopter. Another hypothesis is that β_7 will be significantly > 0 where the probability of adoption would be positively associated with the simultaneous conditions of stronger attitudes favoring the adoption of drip irrigation, more importance attached to what society (or the grower's social norm) deems appropriate behavior, and a sense of more volition in the technology choice.

PBC reflects the extent to which the grower has control over the adoption of drip irrigation. In the vernacular of economics the control variable represents constraints. The control element addresses three distinct ideas: volition, ability, and the availability of resources to invest in drip.

Generally, the model becomes:

$$(5.2)\quad B \sim I = f(Context,\ U^I,\ U^{**},\ Control,\ Interaction\ Terms).$$

Construction of the Empirical Model

The Perceived Behavioral Control variable was measured in the same way as the proxies for as the Attitude and Social Norm variables described in Chapter IV and takes the form of:

$$(5.3) \quad PBC = \Sigma\, c_k * p_k$$

The belief component, c_k, is measured on a probability scale for four belief statements representing latent financial means, volition, and ability. The belief statements include (1) whether regulatory agencies could require growers to use drip irrigation (volition); (2) if using drip was easy or difficult (knowledge or ability); and (3) if investment capital from current income or (4) from borrowing was adequate to invest in drip irrigation. An example of a belief statement is the following:

Regulatory agencies can require me to install a drip irrigation system

likely _____:_____:__*T*__:_____:_____:_____:_____*unlikely*

extremely quite slightly neither slightly quite extremely

For the grower's evaluation of his/her power to comply component, p_k indicates how important control is to the grower. It was assumed that grower's would evaluate financial ability at the highest ranking, "extremely important". Growers were asked to evaluate whether compliance with water technology regulations and control over the adoption of

technology was important to them, as illustrated by the following statement:

Control over the decision to install technology or not is

important _____:__*T*__:_____:_____:_____:_____:_____*unimportant*

extremely quite slightly neither slightly quite extremely

Assume a grower answered "*slightly likely*" (5 on the probability scale) to the belief statement and "*quite important*" (6 on the valuative scale). The control component is then 30 (5 X 6) for this particular dimension. All such dimensions are multiplied and added to form the perceived behavioral control variable, or PCB.

In the Equation 5.3, c_k, is the probability scale measuring the degree of belief about whether the consequence will occur as implemented by the Expectation operator in expected utility. The p_k is the utility received if the consequence occurs.

The "Bagozzi" test was employed to determine the salient control variables. All of the interaction terms of the individual control components (volition, financial means, management ability) were significant at the .01 level. Thus, the Perceived Behavioral Control variable simultaneously represents the effects of management and financial capability and volition.

In applying the double hurdle model to equation 5.1. the assumption that the social norm is only relevant to the first adoption stage is maintained. Thus, the only interaction term that appears in the second

stage adoption decision is the interaction between the Control and Attitude variables.

Model Results

The results of the double-hurdle multiple utility model with control are given in Table 5.1. As with the other iterations of the model, the significance of Inverse Mills Ratio indicates that modelling the adoption decision as a two-stage process is the correct procedure to use. To better understand the analysis of results, each stage of the decision process is discussed separately. All the signs for the parameter values and the marginal effects are as hypothesized.

The First Stage Decision to Adopt or Not Adopt

With the addition of the control variable and the corresponding interaction terms to the multiple utility model, there is a slight change in the importance of the physical environmental variables. Compared to earlier models, SOIL_TYP is less significant in explaining the initial adoption decision. Water quality (WQP), although weak, now becomes somewhat significant. It may be that the Control variable, which represents managerial ability as well as financial means and volition, could have some relationship to the environmental conditions that growers face on the farm.

As was the case in the Derived Demand model and the multiple utility model without control, per acre investment costs and product price both have a significant influence on the first stage adoption decision. A

increase in nominal tomato prices has a positive effect on the probability of adoption and an increase in capital investment costs a negative effect.

Table 5.1. Parameter Estimates for the Double-Hurdle Multiple Multiple Utility Model with Control[1].

Variable	First Stage Decision	Second Stage Decision	$\partial p/\partial x$
CONSTANT (B_0)	-131.06[c] (54.51)	-74.15[c] (19.61)	-8.41
WQP (B_1)	.90[b] (.46)	.71 (.65)	.0[2]
SOIL_TYP (B_2)	.42[c] (.29)	.88[c] (.67)	.03
DEPTH (B_3)	$.64*10^{-4}$ ($.47*10^{-3}$)	$.23*10^{-2a}$ ($.81*10^{-3}$)	$4.07*10^{-6}$
COSTAC (B_4)	$-.62*10^{-2a}$ ($.16*10^{-2}$)	$.17*10^{-3}$ ($.68*10^{-3}$)	-.0004
PRICE (B_5)	18.51[a] (6.21)	9.81[a] (2.97)	1.19
CROP (B_6)	-.10 (.73)	-.52 (.52)	-.006
ATTDRIPT (B_7) (A)	.23[c] (.14)	.12[a] (.04)	.01
SOCIAL NORM (B_8) (SN)	.05[c] (.03)	-	.003
A*SN (B_9)	$-.60*10^{-3c}$ ($.37*^{10-3}$)	-	-.00004
CONDIPT (B_{10}) (C)	.20[b] (.12)	.11[a] (.04)	.01
A * C (B_{11})	$-.22*10^{-2c}$ ($.14*10^{-2}$)	$.11*10^{-2a}$ ($.34*10^{-3}$)	-.00004
SN * C (B_{12})	$-.64*10^{-3b}$ ($.35*10^{-3}$)	-	-.0001
A* SN * C (B_{13})	$-.60*10^{-5c}$ ($.39*10^{-5}$)	-	$3.85*10^{-7}$

Table 5.1. (con't.)

MILLS RATIO	-	2.06[a] (.22)
RHO	-	-.68[c] (.46)
LOG LIKELIHOOD	-	-208.12
Degrees of Freedom	120	120

1. Standard errors in parentheses.
a. Significant at the .01 probability level.
b. Significant at the .05 probability level.
c. Significant at the .10 probability level.

The addition of the control variable changes the significance of the pre-adoption attitudes (A) and the social norm (SN) variables. The parameter on Attitude increases in value, but is less significant compared to the multiple utility model without control. The parameter on the Social Norm variable increases dramatically compared to the previous model and is significant at the .10 level and suggests that growers who are more influenced by social norms will be more likely to adopt. This latter result suggests that in order to understand the effect of social norms on adoption behavior one may have to take into account the degree of control grower's perceive they have over the adoption decision. This may be especially relevant to that part of the control variable that accounts for volition.

The perceived behavioral control variable (PBC) is positive and significant at the .05 level in the decision to adopt or not adopt drip irrigation technology. Thus, the more volition, ability, and financial resources the grower perceives he has, the more likely he/she is to adopt

drip irrigation. This finding suggests that too much regulation could be counterproductive, slowing the move to become an adopter.

As was the case with the interaction term A*SN in the multiple utility model without control, each of the double interaction terms in the model with control are negative. The explanation remains the same in that the control variable (C) has a negative effect on the influence of attitudes (A*C) and social norms (A*SN) on the initial decision to adopt. However, the small size of the parameters and the fact they are only significant at the .10 level indicates that the interaction terms may not be very important in the first stage adoption decision.

The significance and value, albeit both low, of the parameter on the A*SN*C interaction lends some support to the idea that there is an important relationship between all three forces.

The Second Stage Decision of Intensity of Adoption

In contrast to the multiple utility model without control (where both soil type and water quality were significant), the only environmental variable that is somewhat important to the intensity decision in the model with control is soil type. The inclusion of the control variable, in addition to attitudes, suggests that the control variable may be mediating the effects of the environmental factors. Cropping pattern is insignificant.

The economic variables of pumping costs and crop price are highly significant in the second-stage adoption decision, reflecting the same results as the multiple utility model without control.

Grower's pre-adoption attitudes (A), perceptions of control (C), and the interaction term A*C, are all positive and significantly influence the proportion of farm put into drip irrigation. The control variable may reflect the importance of the components related to management and/or financial capability rather than the absolute degree of volition. The positive sign on the interaction term (A*C) shows that the level of control reinforces the influence of grower attitudes towards the profitability of drip in this decision stage. Thus, there is a positive relationship between grower's perceptions of their financial and management capacity, and the perceived degree of volition in adoption decision, to their pre-adoption attitudes concerning the profitability of drip irrigation.

The marginal significance of the interaction terms in the first stage of the adoption decision (AxSN, AxC, and AxSNxC) supports the results of Schifter and Ajzen. On the other hand, the significance of SN*C in the first-stage adoption decision and A*C in the second stage runs somewhat counter to findings in other tests of Planned Behavior Theory (see Ajzen and Madden; Ajzen and Driver). Most tests of Planned Behavior, however, have dealt with trying to predict intentions (I) and have focused on the Intention x PBC interaction, whereas in this study actual behavior (B) is addressed.

According to the sign and significance of interaction term, AxSNxC, a grower who has simultaneously a stronger pre-adoption attitude towards drip irrigation, has more influence from surrounding community groups, and has more volition in choices is more likely to install drip irrigation and to put a larger proportion of their farm in drip irrigation. This result

indicates that it may be unrealistic to expect that grower's could cognitively separate these components into the single effects of attitude (A), community norm (SN), and perceived behavioral control (PCB) in their actual adoption decisions. The finding of significant interactions supports the original formulation of The theory of Planned Behavior (see Ajzen 1991).

Simulation Analysis

In the full model, grower's pre-adoption attitudes and perceived behavioral control are extremely significant in the decision related to intensity of adoption. Thus, a simulation analysis is carried out to illustrate the sensitivity of the proportion of farm area put into drip to changes in attitudes and perceived control.

Figure 5.1 illustrates the sensitivity of the proportion of farm area put into drip irrigation to a change in grower pre-adoption attitudes towards the profitability of drip. For extremely well drained soils, the intensity of drip adoption is insensitive to the level of pre-adoption attitudes. The result indicates that, for growers who have already invested in drip and have extremely well drained soils, pre-adoption attitudes do not affect the intensity of adoption. However, the case is different for growers who farm on well drained or poorly drained soils.

For both well and poorly drained soils there is a positive relationship between pre-adoption attitudes and the intensity of adoption. For any given level of attitude there is more intense adoption of drip on

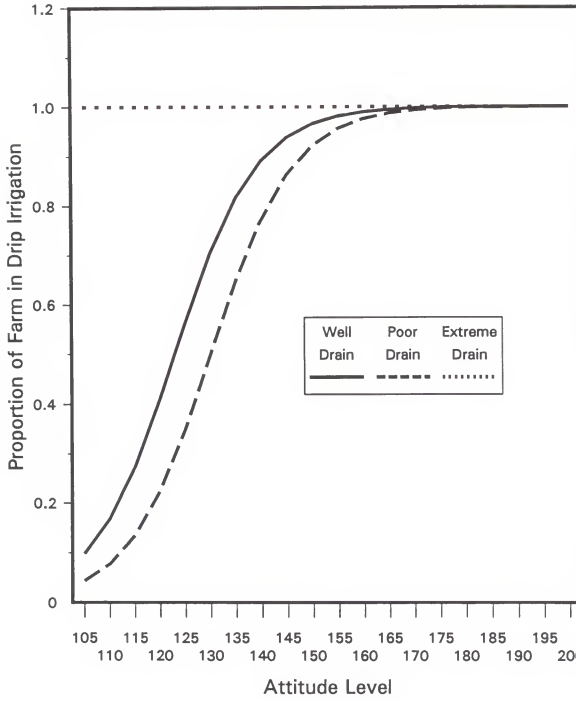

Figure 5.1. Effect of Attitudes on Intensity of Drip Adoption on Tomatoes, 1995

farms with well drained soils compared to farms with poorly drained soils. For example, at an attitude level of 130, the proportion of a farm in drip with well drained soils will achieve 70%, while on poorly drained soils the proportion of farm in drip will only be 50%. Thus, grower's on soils that are poorly drained, i.e. those who have fewer problems with soil moisture retention, have to have stronger attitudes towards the profitability of drip to for any given level of adoption. Finally, the slopes of curves for poorly and well drained soils indicate that a large increase in the proportion of farm area in drip must be accompanied by substantial changes in the pre-adoption attitudes of growers.

Figure 5.2 shows the effect of the control variable on the proportion of farm area in drip irrigation. For each soil type there is a positive response over a fairly narrow range of perceived control. Likewise, for each soil type, there is an increase in the area in drip for fairly small increases in the level of control. This says that for slight increases in the level perceived control (financial means, management capability, and volition) there will be substantially higher increase in the intensity of adoption. In other words, the response of farm area in drip to a change in control is quite elastic, and is much more so than can be seen in Figure 5.1. for changes in pre-adoption attitudes.

General Theoretical Implications

The continued significance of environmental and economic context variables in the multiple utility model with control supports the Theory of Derived Demand (Chapter III) and the findings of previous irrigation

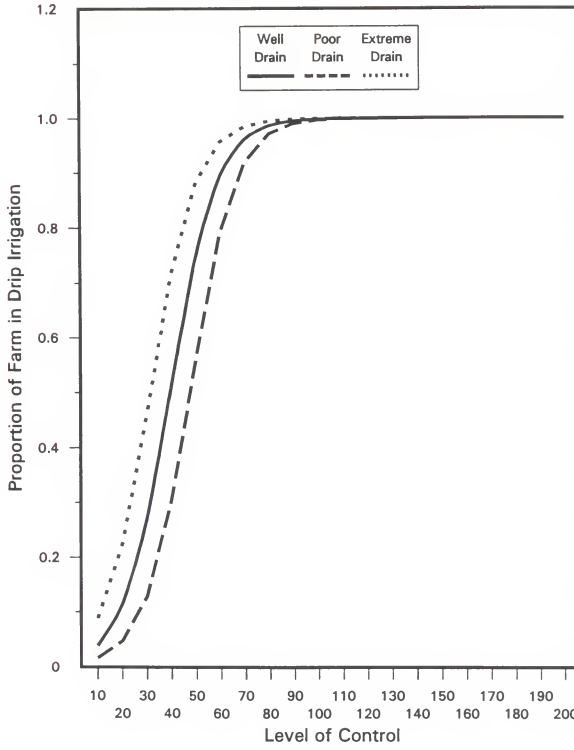

Figure 5.2. Effect of Control on Intensity of Drip Adoption on Tomatoes, 1995

system adoption studies. However, adding grower's perceived behavioral control, pre-adoption attitudes, and social norms results in a more powerful model to explain the factors affecting the initial adopt/not adopt decision and the intensity of adoption. Using the Chi-square test to compare the multiple utility models with and without control results in a χ^2 of 25.76 with 4 df, which is significant at the .005 level. Grower's perceived control involving financial and management capability and volition is therefore important in explaining drip irrigation adoption.

The fact that the perceived behavioral control variable, and its interaction terms, add significant explanatory power to the reasoned action and Derived Demand models suggests that they are not sufficient in determining the factors affecting either the initial adoption decision or intensity of adoption. There are other aspects to control larger than those captured by measuring the contextual environmental and pure economic variables. In this case, it is the control exerted by the water management districts through regulation, the grower's *perception* of his ability to manage drip irrigation, and the grower's *perception* of his/her financial capability.

More specific theoretical and policy implications from the research findings of this dissertation are presented in the next Chapter.

CHAPTER 6
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This dissertation addressed three major objectives. The first was to test a multiple utility conceptualization of the drip irrigation adoption decision *without* control. The second was to test whether the multiple utility model *with* control provided an additional insight into the factors affecting the drip adoption decision. In general, the multiple utility framework tests, with and without control, whether the standard assumption in economics that behavior is based solely on fulfilling a single self-interested, profit maximization utility is viable. The purpose for testing the multiple utility conceptualization is to build upon and enhance current neoclassical economic theory.

A third objective was to investigate the adequacy of the double-hurdle model for analyzing drip irrigation adoption decisions. The findings of this dissertation with respect to these three objectives, and the resulting theoretical, policy, and methodological implications, are discussed separately, starting with the last objective.

The Double Hurdle Model

Chapter III first demonstrated, and subsequent chapters confirmed, that the double hurdle model discriminates between factors that influence the adopt/not adopt decision from those that affect the intensity of

adoption. Policy implications generated are different using the double-hurdle model that those generated by models that use a single probability distribution. More specific information is generated on which to base interventions to encourage adoption. Thus, there is a potential gain in the efficiency in the use of public funds to encourage water conservation through the adoption of drip irrigation.

Multiple Utility Model Without Control

The multiple utility model without control variable constituted a preliminary test of whether there is a social dimension to drip irrigation adoption behavior in addition to purely self-interested motivations. It was found that the multiple utility framework provides a more adequate conceptualization of the adoption decision compared to the single utility Derived Demand framework.

However, while a chi-square test showed that the multiple utility model without control had more explanatory power than the Derived Demand model, there was no evidence that social norms alone effect grower drip adoption behavior for this farm level data. Yet, the attitude variable was better identified when the social norm variable was included. It isolated the effects of the pre-adoption attitude, and suggests overlap in the self-interest and social norm utility.

One possible reason for the lessor role of the social norm than was found in previous work which focused on grower response (Lynne et al., 1995) and in the analysis of the grower response level data for this tomato study (Casey and Lynne, in press) is the issue of specificity discussed earlier. As Ajzen and Fishbeing (1977) showed, it is necessary

to match the level of the variables. If a quite specific behavior like "install drip irrigation on a particular farm" is the dependent variable, then for best results the social norm data must also address that particular field. Similarly, if the behavioral response we are trying to understand is "install drip irrigation on all farms managed (several of the growers managed more than one farm) then the social norm variable may also need to be general, like the one used here. Yet, even though not highly significant, clearly including the social norm variable still shows an improvement even for the farm level analysis.

Multiple Utility Model With Control

The multiple utility model with control incorporates grower's perceptions of their own level of free choice in the adoption decision, ability to manage a drip irrigation system, and the financial means to invest in drip irrigation. The results show that the incorporation of the control variable, in addition to it being significant in-and-of-itself in both stages of the adoption decision, also had a significant impact on the pre-adoption attitudes and social norm variables in the first-stage adoption decision. With the addition of the control variable the social norm variable becomes somewhat significant, giving a modicum of evidence that grower's pursue other goals in addition to, and perhaps in conflict with, maximization of self-interest through profits, even at the field level. There are theoretical and policy implications stemming from the results of Chapters IV and V, discussed separately below.

Theoretical Implications

The results of Chapter's IV and V provide evidence to support the calls of Sen, Hirschman, and Etzioni that the complexity of human nature be reintroduced into economic theory. As Hirschman (1985) claims, economics needs to pay closer attention to the special nature of public morality as an input. The analysis from Chapter V provides evidence for two types of utility which cannot be reduced to a single, self-interested utility. Human choice is multi-dimensional, as was illustrated in Figure 2.1. The empirical findings from both Chapters IV and V suggest that accounting for meta-preferences, as represented by social utility, is important, especially for certain kinds of decisions. Admittedly, the multiple utility model adds complexity, and more expensive data collection, but the findings from this dissertation suggest that the standard model of economic behavior is too parsimonious. Therefore, increased costs of research must be faced.

It appears desirable to embellish standard utility theory in order to better understand and explain cases where people seem to be influenced by both social norms and self-interest. The findings in this dissertation highlight the possibility of rational action even when choices differ from strict profit maximization. An individual might put relatively more weight on social utility in the cognitive, rational thinking process, or may be responding to emotions or norms. At a minimum, applying the multiple utility model allows one to test for social influences over private decision making. Because the decision models incorporating social influences were found to have significantly more explanatory power than those without, it appears necessary to broaden the concept of what is

rational and to develop intervention policies that promote moral suasion as well as standard incentive packages.

The significance of the multiple utility model with control helps address what Kolm (p.22) calls "das Adam Smith Problem" wherein it explains how people can simultaneously display the egoistic behavior of *homo oeconomicus* and his/her concern for others. The results also help us better understand Adam Smith's two books where the dualistic nature of the individual, moral sentiments and individual self-interest, can be simultaneously pursued. Thus, "humans can be concurrently both egoistic and altruistic and not only pursue their self-interest but can also consider the moral dimension of their acts" (Lynne 1995, p.23).

The findings in support for a multiple utility conceptualization of human choice behavior also sustains two of Sen's major claims. First, that commitment is substantively different from sympathy, revealing a dimension of the human psyche pertaining to personal welfare, as unique from personal choices. And second, that the neoclassical model tries to do too much and too little at the same time. It tries to do too much in that choice may often reflect a compromise already made between self-interested and social utility and it may do too little in that the model presumes that one can observe choice to know preferences.

The results of Chapter V indicate that economic modelling that assumes full volition is problematic. The significance of the perceived behavioral control variable verifies there is something less than full volition in the case of drip irrigation adoption by Florida tomato producers.

The evidence that increased volition leads to an increased probability and intensity of drip irrigation adoption has another theoretical implication. Recall in Chapter II that Hirschman warned that meta-preferences reflected in the public spirit (for water conservation in this case) may become scarce "when preached and relied upon to excess" (p.18). The findings here suggest that current water conservation technology regulations could be counterproductive if they are perceived as being excessive. Thus, persuasion to encourage changes in grower beliefs and evaluations of drip irrigation may be a better way to achieve increased rates of adoption.

In general, for the purposes of furthering theoretical development in economics, the results from this dissertation suggest the possibility of synthesis. Including social norms and perceived control links the constrained volition theory of Derived Demand with the multiple utility model. If perceived behavioral control is found not to be significant, one can surmise nearly full volition and the multiple utility model with the contextual variables becomes viable. The point is, one can test how important volition really is in the decision process, rather than having to assume it. When the contextual variables of Derived Demand theory are significant, as is the case in the present study, then Derived Demand theory is also descriptive. The multiple utility model with control, as demonstrated in this dissertation, has the potential for improving the analysis of economic decisions.

Policy Implications

The fact that pre-adoption attitudes, social norms, and control were important in explaining grower drip irrigation adoption behavior has definite implications for agricultural water conservation policy in Florida. As Ajzen (1991, p. 206) has noted: intention, attitude, subjective norm, and perceived behavioral control each reveal "a different aspect of the behavior, and each can serve as a point of attack in attempts to change it".

There are some main policy prescriptions which are consistent with the research findings. Cost share, fuel taxes and technical assistance programs based on research and extension programs could be more effective than setting technology mandates through top-down efficiency standards. The cost share program would respond to the constraints on adoption imposed by the high capital investment costs of drip irrigation and the perceived lack of financial means to invest in drip. Fuel taxes would encourage grower's with access to shallow water tables to consider drip. Finally, a technical assistance program would address grower's perceived lack of ability to manage sophisticated drip irrigation technology.

The problem with setting efficiency standards, which can only be met by drip irrigation, is that it has resulted in micromanagment of on-farm resources by regulatory agencies. This micro-management reduces the perceived control or volition by growers over their technology decisions and could diminish rather than increase the probability of drip adoption and the intensity of effort. Because economic efficiency depends upon a sufficient level of flexibility and volition, a high level of micro-

management in the form of technology regulation can reduce economic efficiency.

One means of increasing flexibility is that regulatory standards for water conservation must have an outcome instead of a technology focus. This approach is supported by Wu et al. and Teague et al. who found that more incentive based (voluntary) programs, worked better in promoting water conservation. By prescribing a specific technology, regulations inflict high costs of compliance on the grower, perhaps including wasted transactions costs in fighting such regulations. The regulatory approach creates major disincentives for a grower that attempts to deal with an environmental problem in an innovative manner. Mandating water allotments or technology standards fails to provide incentives for continued and ongoing innovation and will tend to freeze a status quo until new regulations appear.

Policy tools based on voluntary market incentives may be more effective in encouraging the adoption of drip irrigation. Market incentives help internalize externalities, encourage scrutiny of water use, provide transitional flexibility, and motivates new methods for saving water. Market based incentives include cost share programs, crop subsidies, fuel taxes and tradeable water use permits. Market driven mechanisms add flexibility in terms of the timing and sequencing investments in technology and they also provide continuing incentives for innovation.

Porter and van der Linde note that sound regulatory process is defined by regulations that are clear, that clearly defines who must meet them, and which does not cause an industry to face uncertainty in

interpreting standards or the need to expend resources attempting to clarify them. Different levels in each of the water management districts need to better coordinate and organize themselves so that growers are not forced to deal with multiple parties with inconsistent desires and approaches. A regulatory regime must evolve in which water management districts make a commitment to standards that will be in place for, say, five years, so that growers can lock in and make efficient technology decisions.

The water management districts may need to modify the administrative approach to water conservation. For example, a major goal of the WMD's should be to promote more experimentation for achieving water conservation, not to just lock into one specific technology like drip irrigation. This could be accomplished by sponsoring water conservation research and demonstration projects. Bosch et al. note that regulatory programs may have to be accompanied with education to ensure that growers are adequately informed about the impacts of their water use practices and the availability of new technologies.

Some regulation may be necessary to start the process of technological innovation, supporting the view by Porter and van der Linde. Some tomato growers have adopted drip irrigation in part due to the current or anticipated regulatory requirements. The focus of the regulatory program based on this notion, however, is different than in the micromanagement approach. Rather, a minimalist regulatory program works to find that level of interaction with growers that helps growers feel justified in being involved in water saving activity. While not tested for directly in this study, there appears to be a lower threshold of

regulatory activity which is necessary to spur innovation and implementation of modern water saving technologies. It follows that a regulatory program focused on finding the minimal thresholds, rather than engaging in micro-management through setting technical efficiency standards, would likely result in more benefits for producers and for the larger society that regulatory agencies represent. Higher adoption rates could come from helping growers see not only that their own interests are served, but in better understanding their role in and interdependence with the community that use the same water resource.

The findings appear consistent with explanations for water conserving behavior from the perspective of the minimal justification principle in social psychology (see Lynne et al. 1995). A weaker, more moderate justification for behavior leading to internal control by the grower may be more effective than a highly visible, more demanding external control. Katzev and Johnson found that residential users of electricity were more likely to continue conserving electricity when approached with a small, moderate request as compared to more demanding requests. They demonstrated how the former lead to a longer term commitment to conservation, probably due to changing conservation attitudes, while the latter may lead to only short term responses. Wu et al. also found that more "moderate" requests involving water restrictions would be more likely to result in the adoption of modern irrigation technologies than "extreme" restrictions. The highly visible, external threat from the water management district that the grower's permit would not be renewed unless he/she adopts drip irrigation may well be counterproductive (or at least unnecessary) as the minimal justification

principle would suggest. The principle also seems to suggest there may even be varying thresholds for restrictions, with some farmers responding and some not responding to the same level of external control. Nonetheless, water conservation technology policy and implementation approaches will be improved with a move to the minimal justification idea as the guide to activities aimed at inducing water conservation technologies like drip irrigation.

It is suggested that some of the more restrictive regulatory policies and programs used by Florida's water management districts be reconsidered. An ongoing research program which focuses on the costs and benefits of regulatory policies and processes needs to be initiated. The purpose of such a program would not be to eliminate regulation, but rather to search for the right amount and type of regulation to achieve water conservation goals. The final conclusion is that a shift away from micro-management with more concentration on incentives, minimal justification, moral suasion, and volition would help better achieve Florida's water conservation goals in the long run.

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BIOGRAPHICAL SKETCH

Clyde Franklin Casey was born on December 7, 1951 on Okinawa. He was raised in Los Angeles and attended The California State University at Northridge where he received a Bachelor of Arts degree in political science. Dr. Casey then served with the Peace Corps and the United States Agency for International Development in Senegal, West Africa, where he pursued his interests in agricultural development.

In 1979, Dr. Casey returned to the United States and earned a Master of Professional Studies degree in international agriculture and a Master of Science degree in agricultural economics at Cornell University.

The Cornell experience was followed by another six years in West Africa working as a farming systems economist and an agricultural policy advisor in Senegal and Niger, respectively. He was employed by the Center for Research on Economic Development at the University of Michigan.

In 1989, Dr. Casey started his Ph.D. degree program at the University of Florida and has since accomplished the two goals he set for himself at the outset of the program: applying economics to a real world problem and gaining a better knowledge of American agriculture.

Dr. Casey is currently working on natural resource issues for the World Bank. He plans to continue his research in agricultural technology adoption and regulation.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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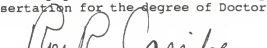

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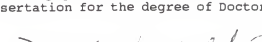

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